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HELICOPTER OBSTACLE STRIKE TOLERANCE CONCEPTS ANALYSIS.(U)

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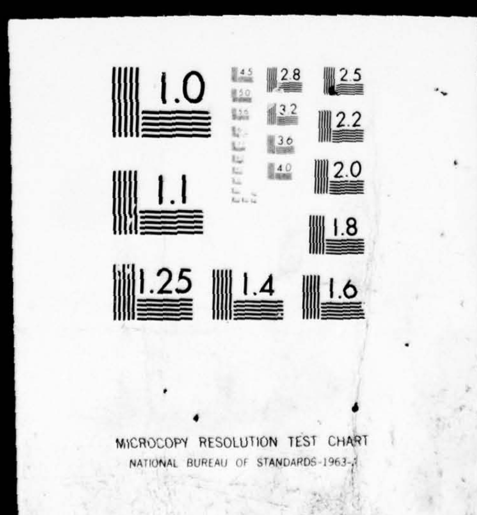

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LEVEL II

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HELICOPTER OBSTACLE STRIKE TOLERANCE CONCEPTS ANALYSIS

Bharat P. Gupta
Bell Helicopter Textron
P.O. Box 482
Fort Worth, Texas 76101

April 1979

Final Report for Period September 1977 - June 1978

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Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

This report provides insight into the helicopter in-flight obstacle strike problem. Reasonable design concepts for improving the obstacle strike tolerance of rotary wing aircraft are presented and strike tolerance design criteria are suggested for current, near-future, and future helicopters. Results also indicate that it would be cost effective to modify current fleet helicopters or to design new ones for obstacle strike tolerance. In-flight obstacle strikes, a serious problem now, will become an even greater problem if the Army is faced with terrain flight combat operations in unfamiliar land areas. The need for hardening Army helicopters for tolerance to in-flight obstacle strikes is established. The results of this contract will be integrated into future reasearch and development programs that will further define the technical feasibility of obstacle strike tolerance concepts while assessing their application practicality.

LeRoy T. Burrows of the Aeronautical Systems Division served as Project Engineer for this effort.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A large number of obstacle strikes have occurred during Army helicopter combat missions and nap-of-the-earth (NOE) training missions. Obstacle strike tolerance becomes particularly important for NOE flights in areas containing many obstacles, such as western Europe. → over

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This report defines the obstacle strike problem, particularly for tree and wire strikes. Only a small percentage of obstacle strikes produce accidents, but these accidents account for a high proportion of helicopter damage costs. Tree strikes are more common than wire strikes, but the wire strikes are more likely to cause accidents. Generally, the main and tail rotors are most commonly struck, but a high proportion of wire strikes also occur on the fuselage.

Helicopter obstacle strike tolerance designs for rotors, fuselage, and controls are analyzed and the most promising concepts are selected for both existing and future helicopter systems. In addition, obstacle strike tolerance design criteria are defined.

Design changes to protect fuselage and controls can be incorporated on existing helicopter systems through retrofit in a cost effective manner (damage cost savings are expected to offset engineering change costs). The obstacle strike protection of future Army helicopter systems can be enhanced through application of selected design concepts for rotors, fuselage, and controls. With these improvements, the flight safety of Army helicopters will be enhanced during all-weather daytime and nighttime NOE from the point of view of obstacle strikes.

PREFACE

This report covers the work accomplished during the 10-month period from September 1977 through June 1978.

The work outlined herein was performed under U. S. Army Contract DAAJ02-77-C-0049 and under the technical cognizance of Mr. LeRoy T. Burrows, Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia.

This program was conducted at Bell Helicopter Textron (BHT). Principal investigator for this program was Dr. Bharat P. Gupta. Major contributors were Mr. John E. Brunken and Mr. Durward E. Rutledge.

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1. INTRODUCTION

Obstacle strikes are a serious threat in military helicopter operations. A large number of tree/wire strikes have occurred during Army helicopter combat missions and nap-of-the-earth (NOE) training missions. Obstacle strike tolerance becomes particularly important for NOE flights in areas containing many obstacles, such as in Western Europe. In addition, obstacles such as wires might be used by an enemy as countermeasures against helicopter penetration. Viable obstacle strike-tolerant concepts and design criteria should be developed to reduce the frequency and severity of Army helicopter mishaps attributable to in-flight obstacle strikes. The improvements in obstacle strike tolerance should increase the effectiveness of Army helicopter systems in all-weather, daytime and nighttime, and NOE, low level, and contour flights.

There are many factors that influence the design process associated with obstacle strike-tolerant concepts. First, for the two most encountered obstacles, wires and trees, the helicopter strike protection is achieved differently. Therefore, different concepts are needed for protection against trees and wires. The other important factor influencing the design process relates to the helicopter area that is being protected against obstacle strikes. The percentage distribution of the helicopter areas being struck (main rotor, tail rotor, fuselage and landing gear, main rotor hub, and controls) are different when only wire strike accidents are considered than when only tree strike accidents are considered. A practical consideration of the operational effectiveness of the obstacle strike design concepts necessitates proper accounting of these factors.

Before improvements in the obstacle strike tolerance of present and future Army helicopter systems are accomplished, knowledge of the obstacles and sizes to which current helicopters are reasonably strike tolerant should be defined, and specified as critical obstacles. The desirable design concepts that improve the obstacle strike tolerance should then be established, and the impact of obstacle strike tolerance design features on cost and on performance and operational capabilities of Army helicopter systems must be determined.

2. HELICOPTER OBSTACLE STRIKE PROBLEM DEFINITION

2.1 THE NEED FOR OBSTACLE STRIKE PROTECTION

The inherent design and usage of a helicopter places it in environments where it is exposed to various obstacles such as trees and wires. U. S. Army helicopter employment doctrine, with increased emphasis on nap-of-the-earth (NOE) flying, increases exposure of the aircraft to these obstacles. In order to verify the need for obstacle strike protection and then determine what protection is actually needed, U. S. Army helicopter mishap information was used as the primary data source for this study. The U. S. Army Agency for Aviation Safety (USAAAVS) furnished a computer tape containing pertinent data on all rotary wing mishaps involving an obstacle strike during the time period 1968 through part of November 1977. However, for several reasons, BHT analyzed only those mishaps occurring subsequent to 1971. First, the total volume of information was too large to allow thorough analysis during this limited effort. Second, the Army's emphasis on NOE expanded in 1972; therefore, subsequent information is actually more valid for this study. Third, combat-related mishaps ceased in 1973 with the end of the Vietnam involvement. Further, previous studies (such as Boeing's wire strike analysis, Reference 1) covered the earlier period.

Evaluation of the mishap information was accomplished using worksheets, such as Figure 1, for some of the data, and summary sheets, such as Table 1 and the tables in Appendixes A and B. The term "accident" applies to total loss, and major and minor damage occurrences; whereas "mishap" includes accidents, incidents, and forced and precautionary landings. Table 2 summarizes the Army helicopter accidents, mishaps, and obstacle strikes by year. Figure 2 shows graphically the accident rates for all accidents and for obstacle strike accidents only. Table 3 provides a cost breakdown by year of the obstacle strikes, for accidents only and for all mishaps. Figure 3 shows the obstacle strikes as percent of accidents and all mishaps.

As shown in Table 1, there were 200 accidents and 1181 mishaps involving an obstacle strike, either as a primary or secondary causal factor. The aircraft damage cost for the 93-month period was over $40,880,000, with 256 personnel injuries and 100 fatalities occurring. Averaging approximately 170 obstacle strike mishaps per year ($5,254,000 and 51 casualties a year), the need for obstacle strike protection is evident.

---

[1] Gonsalves, J., WIRE STRIKES, AN ANALYSIS OF ARMY HELICOPTER EXPERIENCE, JULY 1967 THROUGH NOVEMBER 1973, Boeing Vertol Report No. D210-10728-1, January 1974.

MODEL UH-1

	DATE	TIME	A/C S/N	M/C	GEO. LOC.	SURV.?	INJURIES	A/C DMG. COST	MISSION	BEFORE STRIKE: FLT. PH.	BEFORE STRIKE: SPEED	BEFORE STRIKE: HEAD.	BEFORE STRIKE: ALT.	BEFORE STRIKE: ATT.	DID PILOT SEE OBS.?	SITE ENV.	WX.	SEQUENCE OF EVENTS	OBSTACLE DESCRIPTION	A/C CONTACT POINTS	EFFECT ON AIRCRAFT: CONTROL	EFFECT ON AIRCRAFT: STRUCTURE	POST CRASH: FIRE	POST CRASH: XMSN. DISPL.	POST CRASH: A/C ATT.	REMARKS
P	1/77	DAY 0946	H	6	CON.	SURV.	0	0	TRAIN	NOE	0	0	20'		UNK	TREES			SAGUARO CACTUS	M/R BLADES			NO			
P	1/77	DAY 1100	"	4	COM.	SURV	0	12,066	TRAIN	NOE	60	0	65'		NO	TREES, MTS.			UNK. SUSPECT TREES	M/R BLADES			NO			
P	1/77	DAY 1145	"	4	COM	SURV.	0	12,066	TRAIN.	NOE	0	0	0		YES	TREES SLOPE			TALL DEAD TREE	M/R BLADES			NO			O/R 12" OF BLADE
P	1/77	DUSK 1715	"	4	COM	SURV.	0	3,896	TRAIN.	TO	0	0	5'		YES	TREES LEVEL			TREE	M/R BLADE(1)			NO			[illegible] FRACTURE 3' FROM TIP
P	1/77	DAY 1655	"	4	CON.	SURV.	0	138	TRAIN.	TO	20	360	0		YES	TREES			TREE LIMB	M/R BLADES			NO			
P	1/77	DAY 1200	M	4	NON-CON.	SURV.	0	7,722	TRAIN.	CRUISE [illegible]	80	150	55'		YES	TREES LEVEL		[illegible]	TREE	M/R BLADE			NO			ALASKA
P	1/77	DAY 1100	H	4	NON-CON.	SURV.	0	7,394	SERV.	[illegible]	40	100	50'		YES	TREES LEVEL			TREE 1-1½" DIA.	M/R BLADE			NO			ALASKA
P	1/77	DAY 0830	"	4	NON-CON.	SURV.	0	7,394	SERV.	[illegible]	30	080	50'		UNK.	[illegible]			TREE	M/R BLADE			NO			ALASKA
P	2/77	DAY 1425	"	6	NON-CON.	SURV.	0	0	TRAIN.	CRUISE	>0	0	>0		NO	PREP.			KITE (STRING)	SWASH-PLATE			NO			STRING WRAPPED AROUND SWPL.
P	2/77	DAY 1100	"	6	COM.	SURV.	0	0	TRAIN.	NOE	0	0	0		YES	TREES			TREE LIMBS	M/R BLADE			NO			[illegible] TIP CAP
P	2/77	NITE 2010	"	4	COM.	SURV.	0	224	TRAIN.	CRUISE	60	210	<100'		NO	[illegible]			POWER LINE 1½", 6600V	LANDING & SEARCH LIGHTS	NO		NO			AUTO [illegible] 2 MAR 77
P	2/77	DAY 1335	"	4	CON.	SURV.	0	12,066	SERV.	[illegible]	15	261	>75'		YES	TREES MTS.			TREE	M/R BLADES			NO			[illegible]
P	2/77	DAY 1550	"	1	COM	SURV.	1 MAJ, 2 MIN	618,055	TRAIN.	NOE	30	270	0		UNK.	[illegible] SLOPE			BANK OF RAVINE	M/R BLADE			YES			[illegible] 16 MAR 77
P	2/77	DAY 1350	"	6	CON.	SURV.	0	0	TRAIN	NOE	0	0	0		NO	TREES			COMM. WIRE (BETWEEN TREES)	UNK.			NO			NO DMG.; WIRE UNMARKED
P	3/77	DAY 0910	"	4	NON-CON.	SURV.	0	6,033	SERV.	[illegible]	0	330	0		UNK.	PREP. [illegible]			(UNCHARTED) [illegible] ANTENNA	M/R BLADE			NO			PUNCTURED BOTTOM TO TOP
P	3/77	DAY 1600	"	6	CON.	SURV.	0	0	TRAIN.	APPR.	0	0	0		YES	TREES			PINE TREE LIMBS	M/R BLADES			NO			
P	3/77	NITE 2100	"	4	COM.	SURV.	0	1,036	TRAIN.	[illegible]	65	150	0		YES	TREES			TREE	NOSE [illegible]			NO			[illegible]
P	4/77	DAY 1030	"	6	CON.	SURV.	0	0*	TRAIN.	[illegible]	0	0	0		UNK.	TREES		BLEW INTO M/R	DEAD TREE LIMB	M/R BLADE			NO			[illegible]
P	4/77	DAY 1030	"	6	CON.	SURV.	0	0	TRAIN	NOE	0	0	0		NO	[illegible]			LOOSE BRUSH	T/R BLADE			NO			[illegible]
P	4/77	DAY 1338	"	4	CON.	SURV.	0	649	TRAIN.	[illegible]	40	275	60'		NO	[illegible] LEVEL			GOLF BALL	T/R			NO			
P	4/77	DAY 1100	"	6	CON.	SURV.	0	0	TRAIN.	NOE	0	0	0		UNK.	TREES			TREE	M/R BLADE			NO			
P	4/77	DAY 0915	"	6	CON.	SURV.	0	0	TRAIN.	NOE	0	0	0		UNK.	TREES			SMALL PINE TREE	M/R BLADE			NO			SMALL DENT ON UNDERSIDE
S	5/77	DAY 0945	"	6	CON.	SURV.	0	0	TRAIN.	[illegible]	0	0	2'		NO	TREES		[illegible]	TREE	M/R BLADE			NO			[illegible]
P	5/77	DAY 0820	"	4	NON-CON.	SURV.	0	6,033	TRAIN.	[illegible]	30	030	40'		YES	TREES			WIRES (3)	M/R, SKID M/R BLADE			NO			[illegible]
P	5/77	DAY 1550	"	6	CON.	SURV.	0	0	TRAIN.	T/O	•	0	0		UNK.	TREES			SMALL TREE LIMBS	M/R BLADES			NO			
P	5/77	DAY 0930	"	4	NON-CON.	SURV.	0	13,286	TRAIN.	NOE	0	070	0		UNK.	TREES, [illegible]			TREE LIMB	M/R BLADE			NO			
P	6/77	DAY 1210	"	4	CON.	SURV.	0	12,700	TRAIN.	NOE	30	330	0		UNK.	TREES [illegible]			[illegible] WIRE	UNK.			NO			A/C IN FLIGHT R/M BANK
P	6/77	DAY 0915	"	4	NON-CON.	SURV.	0	12,660	TRAIN.	[illegible]	0	065	0		UNK.	TREES			TREE LIMBS	M/R BLADES			NO			[illegible]
P	6/77	DAY 1820	"	2	CON.	SURV.	0	45,571	SERV.	[illegible]	0	115	0		NO	TREES SLOPE		UNK	8" TREE	UNK			NO			NO BRIEF; [illegible]
P	6/77	DAY 1310	"	6	CON.	SURV.	0	0	SERV.	[illegible]	100	0	0		UNK.	PREP.			BIRD	WIND-SHIELD			NO			
																TREES			TREE	M/R			NO			

Figure 1. Helicopter Obstacle Strike Study Worksheet.

TABLE 1. SUMMARY: ALL OBSTACLE STRIKES

MODEL: ALL R/W

YEAR: 1971-1977

● CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ1-3	Σ1-8
NO. MISHAPS	111	71	18	852	0	127	0	2	200	1181
NO. MISHAPS W/ INJ.	73	28	2	5	↕	0	↕	0	103	108
TOTAL NO. INJURIES	199	49	2	6	↕	↕	↕	↕	250	256
NO. MISHAPS W/ FATAL.	45	0	0	0	↕	↕	↕	↕	45	45
TOTAL NO. FATALITIES	100	↕	↕	↕	↕	↕	↕	↕	100	100
NO. NON-SURV. ACC.	27	↕	↕	↕	↕	↕	↕	↕	27	27
NO. POST-CRASH FIRES	21	0	0	0	↕	0	↕	0	21	21
DAMAGE COST	31,268,901	4,476,789	600,105	4,529,903	0	72	0	4723	36,345,795	40,880,493

● WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	76	1064	41

VISIBILITY @ OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
44	2	4	3	2	5	17

VIS. OBSTRUCT.?	
YES	NO
40	52

● FLIGHT

	MISSION			
	TRAIN.	SERV.	COMBAT	?
NO. MISHAPS	605	276	297	3

PHASE OF FLIGHT @ EMERGENCY						
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	GND T
116	228	276	305	185	15	? 149

LOCATION	
CONUS	NON-CON.
685	496

TIME OF DAY	
DAWN	16
DAY	1017
DUSK	42
NIGHT	105
?	1

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	201	647	77	125	84	83	144

ALT. AGL (EMERG. - TERMINATION)				
0-50'	51'-100'	101-500'	500'+	?
836	65	49	82	149

	AIRSPEED @ OBSTACLE IMPACT (KTN.)							
	0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	551	85	41	59	37	106	51	251

ATTITUDE @ OBST. IMPACT			
HORIZ.	ROLL.	PITCH UP	PITCH DN.
44	8	4	1

● OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	60	85	1036

OBSCURED ?		
TOTAL	PARTIAL	NO
14	21	13

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	?
104	706	171	155	45

	WHERE STRUCK AIRCRAFT									
	MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING	OTHER	?
NO. MISHAPS	620	16	148	21	48	53	28	2	15	231

WIRE / CABLE				
PWR.	TELE.	GUY	OTH.	?
60	31	3	13	64

TABLE 2. U.S. ARMY HELICOPTER MISHAP SUMMARY

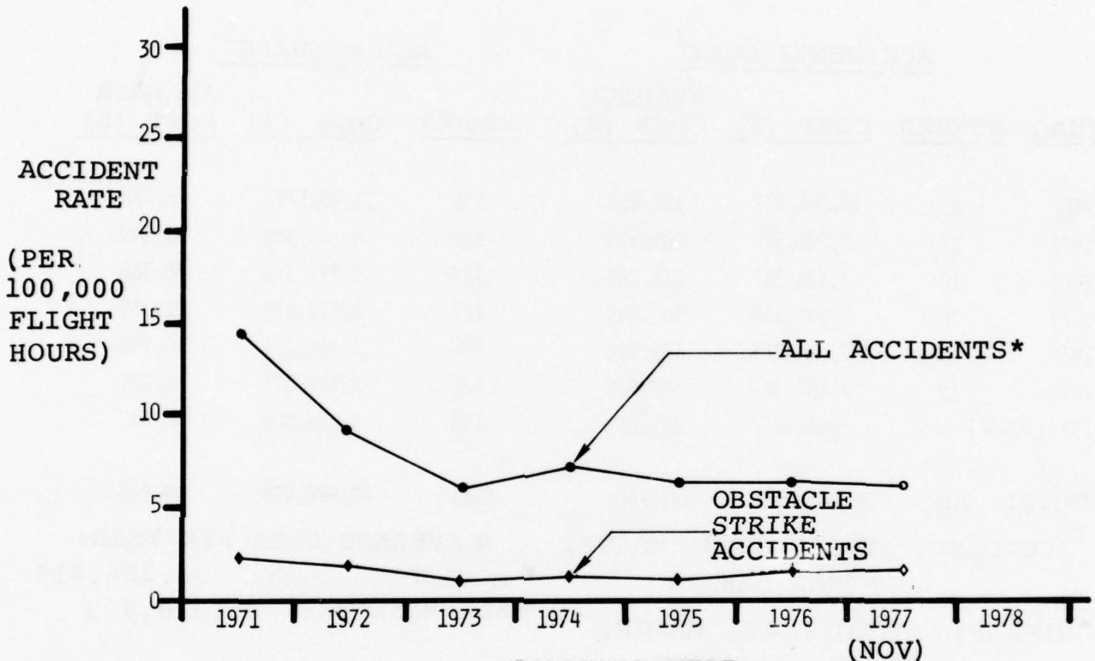
(USAAAVS)

	ALL MISHAP OCCURRENCES		OBSTACLE STRIKES ONLY	
YEAR	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]
1971	502	4319	81	336
1972	186	2389	37	135
1973	96	2201	16	123
1974	98	2519	16	117
1975	83	2695	15	162
1976	81	2038	19	170
(NOV.) 1977	64	1901	16	138
● TOTAL	1,110	18,062	200	1,181

● OBSTACLE STRIKES INVOLVED IN:
- 18.0% OF ACCIDENTS
- 6.5% OF MISHAPS

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS



SOURCE: USAAAVS

*ACCIDENT: TOTAL LOSS, MAJOR & MINOR DAMAGE

Figure 2. U.S. Army Helicopter Accident Rates.

TABLE 3. U.S. ARMY HELICOPTER OBSTACLE STRIKE COSTS

	ACCIDENTS ONLY[1]			ALL MISHAPS[2]		
YEAR	NUMBER	COST ($)	AVERAGE COST ($)	NUMBER	COST ($)	AVERAGE COST ($)
1971	81	10,761,877	132,863	336	11,951,790	35,570
1972	37	3,826,378	103,415	135	4,190,389	31,040
1973	16	3,494,317	218,395	123	3,737,519	30,386
1974	16	2,285,516	142,845	117	2,613,231	22,335
1975	15	2,593,703	172,914	162	3,191,278	19,700
1976	19	7,581,857	399,045	170	8,487,077	49,924
1977 (NOV)	16	5,802,147	362,635	138	6,709,209	48,617
● TOTAL	200	36,345,795	181,730	1181	40,880,493	34,615

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

● AVERAGE COST PER YEAR:

- ACCIDENTS ONLY: $5,254,814
- ALL MISHAPS: $5,910,433

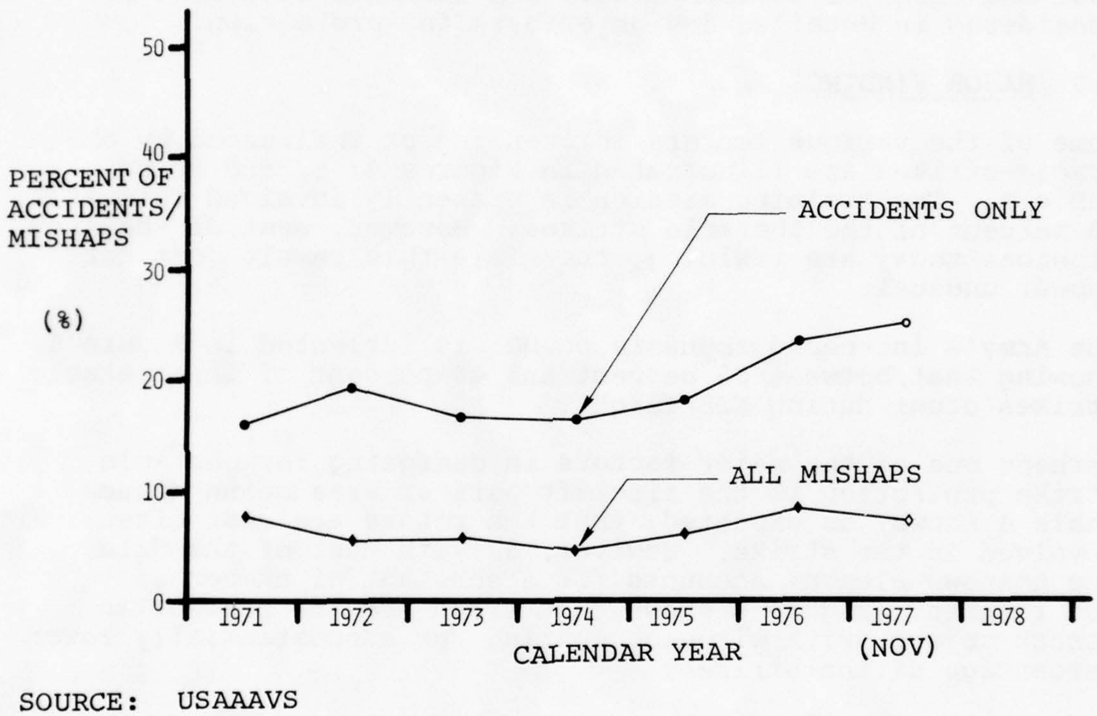


Figure 3. U.S. Army Helicopter Obstacle Strikes as Percent of Accidents and All Mishaps.

2.2 THE TYPE OF OBSTACLE STRIKE PROTECTION

The type of protection needed is a function of several variables as illustrated on the summary sheets. The type of helicopter and its usage is a major factor affecting its exposure to obstacles. Further, the type of obstacles to which exposed also depends upon the type of aircraft. Factors affecting some of the individual model helicopters are summarized in Appendixes A and B. In general, the Army helicopter results are biased toward the UH-1, since approximately 52 percent of the Army inventory are presently UH-1s. However, cost and usage of various models are elements that must be considered in detailed design efforts for protection.

2.3 MAJOR FINDINGS

Some of the various factors influencing or influenced by obstacle strikes are illustrated in Figures 4, 5, and 6 and Table 4. The training mission is presently involved in over 70 percent of the obstacle strikes. However, most of the Army missions today are training, therefore this result does not appear unusual.

The Army's increased emphasis on NOE is reflected in Figure 5, showing that between 35 percent and 40 percent of the obstacle strikes occur during NOE flight.

Perhaps one of the major factors in designing for obstacle strike protection is the aircraft part or area being struck. Table 4 shows, as expected, that the rotors are most often involved in the strike. However, as with most of the data, the unknown element accounts for a substantial number of occurrences. Figure 6 shows that trees are the most often struck object, with wires accounting for a substantially lower percentage of the strikes.

One of the recurring problems in analyzing the data was the amount of unknown or incomplete information provided by the computer tape. Review of the actual accident report often reveals additional details, such as detailed obstacle and strike area descriptions.

2.4 DEFINITION OF HELICOPTER PROTECTION AREAS

The helicopter rotors are the most commonly struck area of the aircraft. However, the sheer number of occurrences does not necessarily reveal the most important areas needing protection. The effects of the strike must also be evaluated. For example,

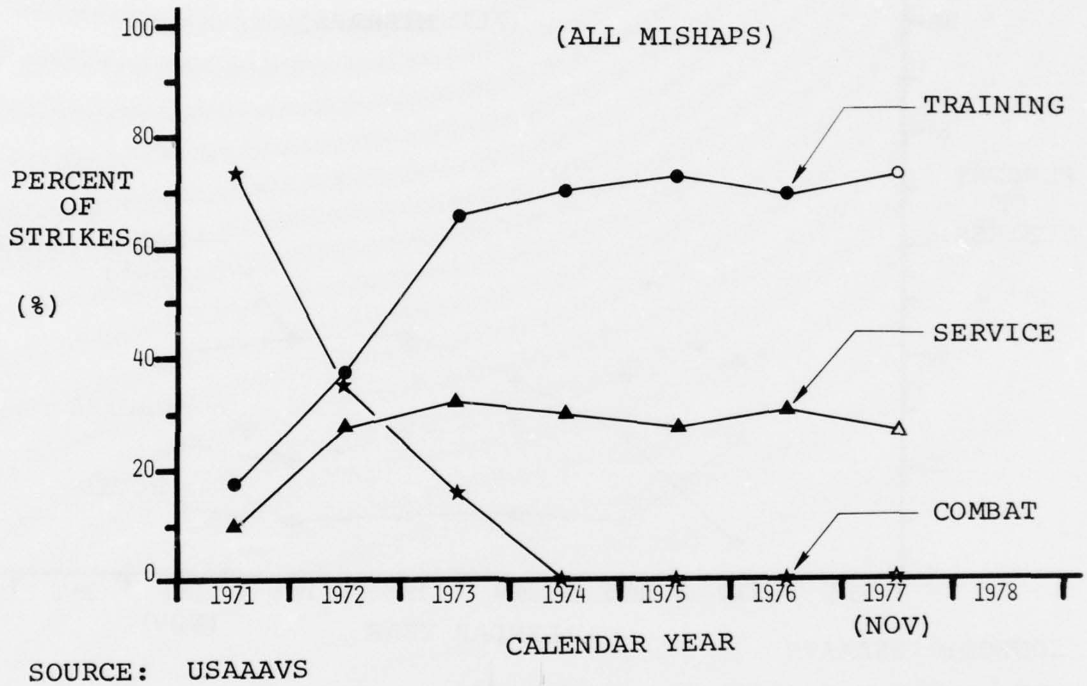
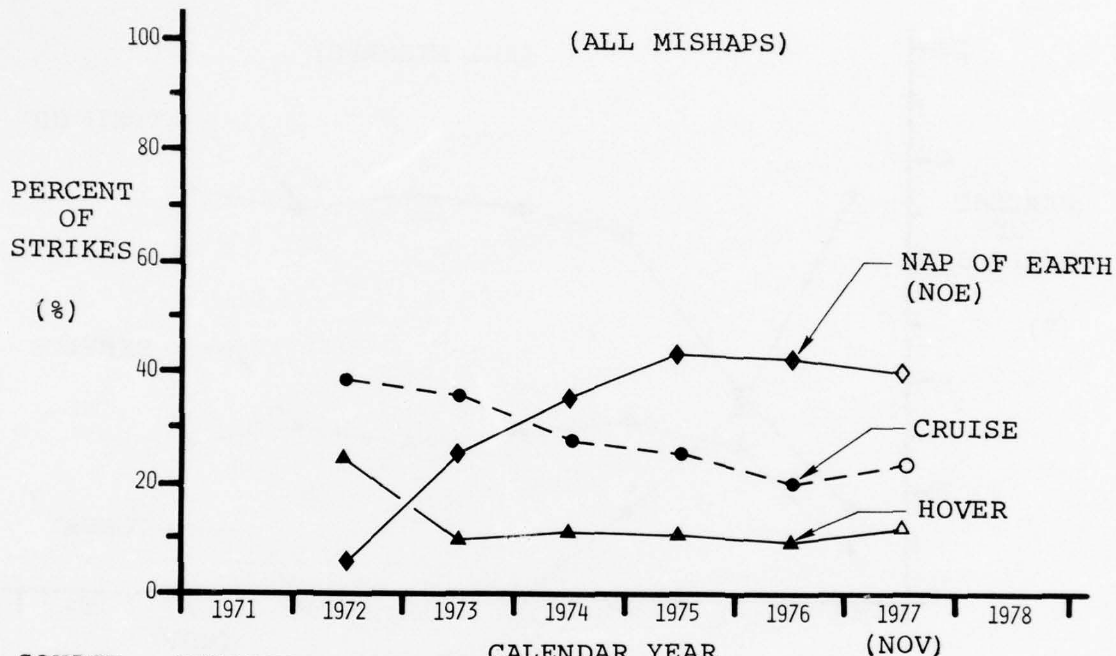


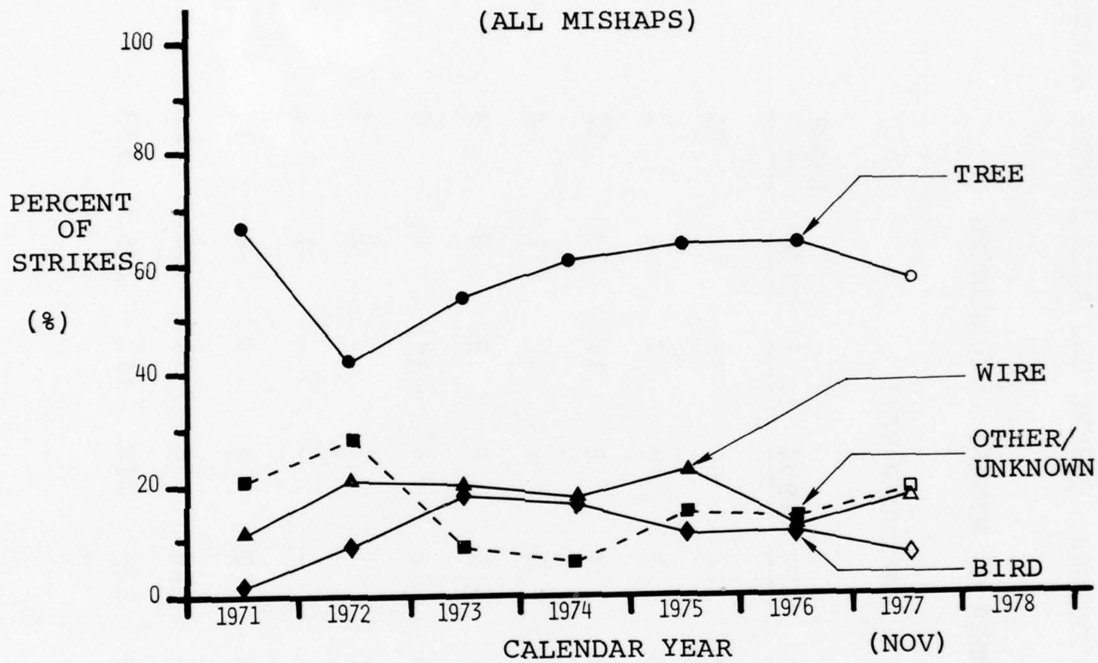
Figure 4. U.S. Army Helicopters: Percent of Obstacle Strikes Occurring During Various Types of Missions.



SOURCE: USAAAVS

NOTE: NOE NOT CODED PRIOR TO 1972

Figure 5. U.S. Army Helicopters: Percent of Obstacle Strikes Occurring During Various Phases of Flight.



SOURCE: USAAAVS

Figure 6. U.S. Army Helicopters: Percent of Obstacle Strikes Involving Various Types of Obstacles.

TABLE 4. ALL HELICOPTERS: WHERE OBSTACLE STRUCK AIRCRAFT

NUMBER OF MISHAP OCCURRENCES

CALENDAR YEAR

AIRCRAFT AREA	1971	1972	1973	1974	1975	1976	(NOV) 1977	TOTALS 1971-1977	TOTALS 1972-1977
M/R BLADE	175	52	64	68	85	95	81	620	445
MAST	4	3	1	-	2	4	2	16	12
TAIL ROTOR	49	19	14	5	16	23	12	148	99
TAIL BOOM	8	4	1	1	2	1	4	21	13
WINDSHIELD	8	4	5	6	8	8	9	48	40
NOSE	7	5	11	4	10	8	8	53	46
LANDING GEAR	12	4	1	2	3	1	4	28	16
WING	-	-	-	-	-	1	1	2	2
OTHER	2	3	2	1	4	4	10	15	13
UNKNOWN	77	13	26	31	32	30	22	231	154
TOTALS	342	107	125	118	162	175	153	1182	840

SOURCE: USAAAVS

main rotor tree strikes are frequent, but the costs, both in dollars and casualties, are low. Examples of this are shown in Figure 1 and Appendix B. Wire strikes are fewer in number, but higher in cost, as shown in Appendix B. Therefore, the emphasis for protection must be determined from an evaluation of helicopter area (main rotor, tail rotor, fuselage, landing gear) and the effects of a particular type of obstacle striking that area. The actual percentages of tree and wire strikes for specific helicopter areas are discussed in Sections 6 and 7.

3. CONCEPT FORMULATION

3.1 CRITICAL OBSTACLES AND DESIGN CONSIDERATIONS

In terms of frequency of occurrence of obstacle strike mishaps, the tree strikes were most common. For example, during the period from 1975 to late 1977, for helicopter Models UH-1D/H, 68.3 percent of the obstacle strikes were tree strikes, 11 percent were wire strikes, and the remaining were bird strikes, water strikes, etc.

In terms of cost and severity, the total obstacle strike cost (less personnel cost) during the 1975 to late 1977 period was approximately $6.997 million. Out of this total, the cost of wire strike accidents (mishap classes one through three) during the same period was $2.053 million, and the cost of tree strike accident was $4.112 million. Expressed in percentages, the cost of wire strike accidents was 29.3 percent of the total obstacle strike cost, and the cost of tree strike accidents was 58.8 percent of the total. Thus, the tree and wire strike accidents accounted for 88 percent of the total cost of obstacle strikes. The design concepts, therefore, should be primarily developed for protecting the helicopter against trees and wires.

The tree sizes varied from less than 1 inch in diameter to over 9 inches in diameter. The important wire types have been found to be power and telephone wires. In some instances, multiple wires were encountered.

For the purpose of obstacle strike protection, the helicopter was divided into four major areas:

- Main rotor
- Tail rotor
- Fuselage and landing gear
- Main rotor hub and controls

The concept designs were carried to sufficient detail to define the configuration, weight, structure, and cost trends. Some of the concepts proposed in this section have been taken from previous blade strike protection improvement efforts, while others are relatively recent concepts. The proposed concepts have been developed to different degrees. The concept designs and the degree to which they have been developed have been described in subsequent sections.

3.2 PRELIMINARY ANALYSES

Preliminary analyses were carried out in support of design work. Following are the important considerations:

- Prevention of loss of control due to imbalance (main and tail rotors)
- Effect of rotor characteristics on the deformations and loads at local strike points and transient structural response
- Reducing blade replacement due to slight damage

3.2.1 Prevention of Loss of Control Due to Imbalance

BHT computer program C-81 is a rotorcraft flight simulation program that includes a time-variant aeroelastic rotor analysis for computing the distribution of rotor oscillatory loads. Besides the loads, the analysis can model steady-state level flight and also simulate maneuvers after a trimmed flight solution is obtained.

The C-81 program has been modified recently (under U.S. Army Applied Technology Laboratory Contract DAAJ02-75-C-0049, Rotor Blade Dynamic Response and Ballistic Damage Survivability) so that unsymmetrical rotor configurations (Reference 2) can be simulated. This new analysis is referred to as SLAMUR (Straight Line Analytical Model for Unsymmetrical Rotors).

The capabilities of SLAMUR were used for the purpose of designing the strike-tolerant main and tail rotor tips. For Model UH-1H, a 50-knot level flight condition was established. Then, tip losses in the range of 0.5 to 1.5 percent of the total blade mass were simulated for the main rotor. A convergent SLAMUR solution could be obtained for a tip loss up to 1.5 percent. The lateral and vertical cg accelerations are plotted in Figure 7. The ship attitude following a 1.5-percent mass loss at the tip is shown in Figure 8. The attitudes shown following the strike are without pilot inputs. The helicopter is, however, controllable up to 1.5-percent tip loss.

Having determined the controllability, the fatigue life of the damaged main rotor blades was determined by calculating the increases in beam and chord blade loads due to imbalance. The spanwise distribution of oscillatory beam and chord loads is shown in Figure 9.

The fatigue condition of Station 192 is most critical; the chordwise loads increase by 37.5 percent at this station. The remaining fatigue life, assuming the worst condition for this case, is 1.96 hours. This remaining fatigue life is assumed

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[2]Viswanathan, S.O., Myers, A. W., and McCarty, T. T., AN ANALYTICAL MODEL FOR DESCRIBING THE RESPONSE OF AN UNSUMMETRICAL ROTOR, Presented at the 33rd Anaual National Forum of the American Helicopter Society, May 1977.

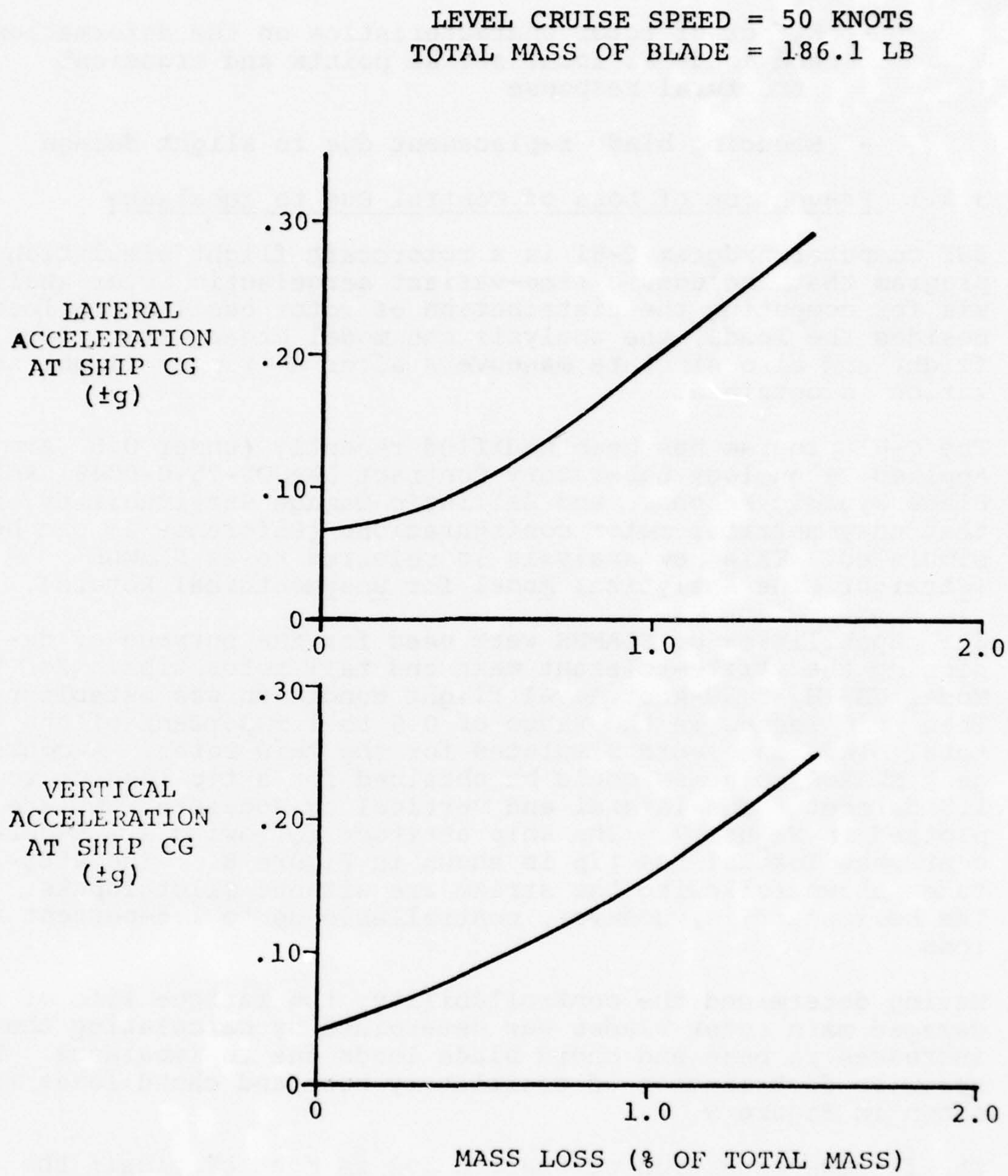


Figure 7. Vibrations at Ship CG Following Mass Loss at Tip of UH-1H Main Rotor Blade

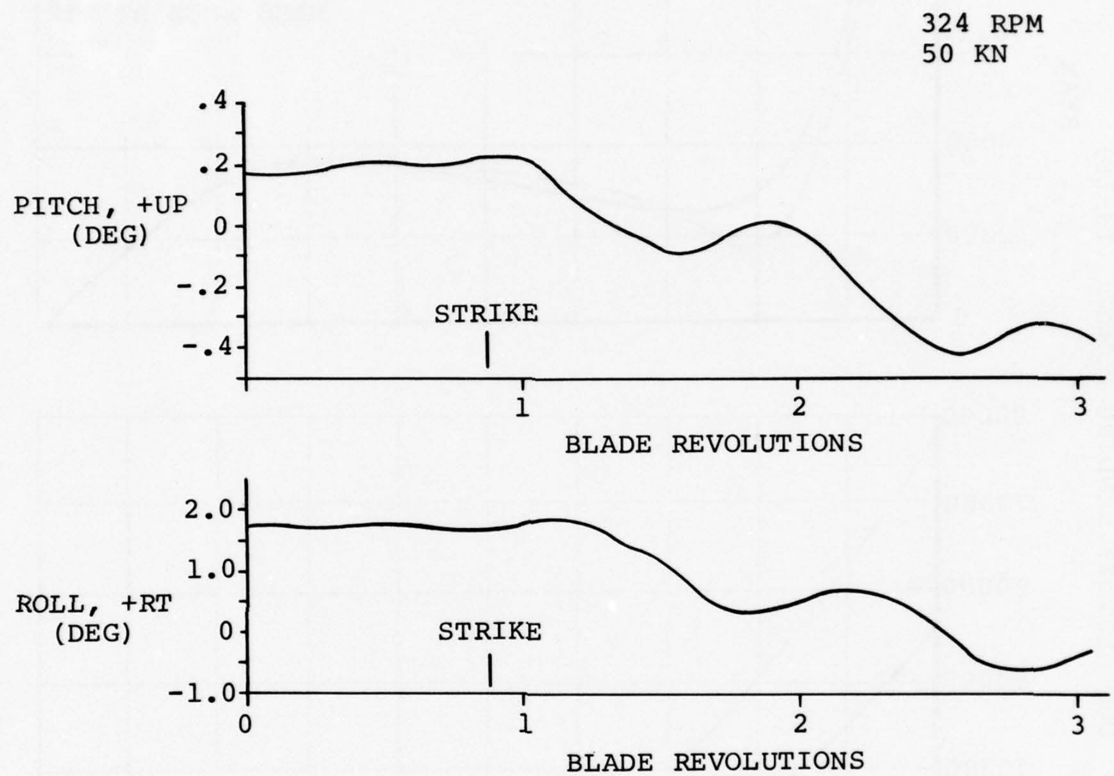


Figure 8. Ship Attitude Resulting from 1.5% Mass Loss at Tip of UH-1H Main Rotor Blade

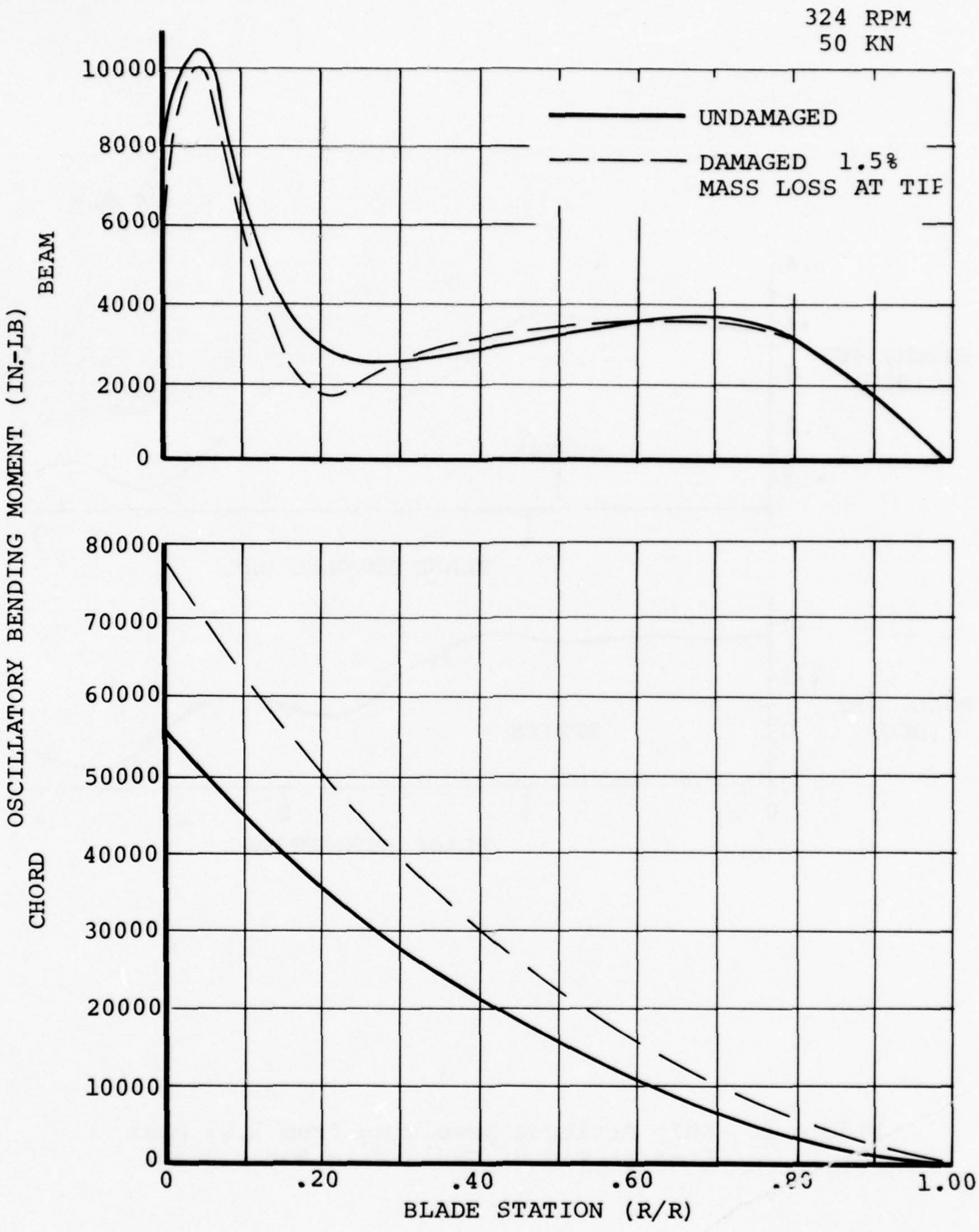


Figure 9. UH-1H Blade Loads for Undamaged Blade and For Blade Following Tip Loss

to be sufficient for the helicopter to complete the mission after the strike occurs.

3.2.2 Effect of Rotor Characteristics on the Deformations and Loads

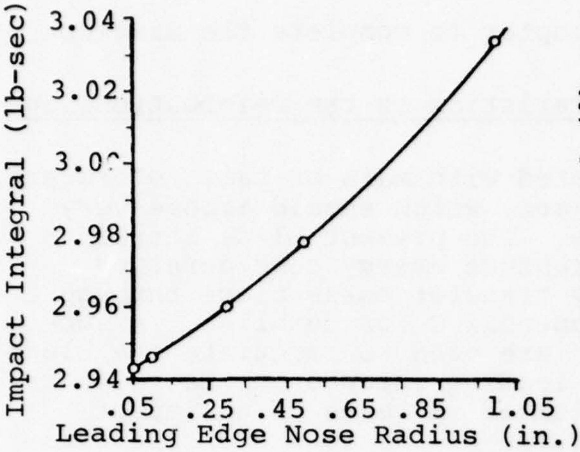
The typical tip speeds associated with main or tail rotors are in the neighborhood of 700 ft/sec, which should impose very high loading rates in a strike. The present blade strike analysis is based on a local rupture energy consideration where, in a strike, the energy transfer takes place through stress wave initiation (See Appendix C for details). A succession of such "microimpacts" are used to calculate the blade loading during a strike. The loading imposed on the rotor as a result of the strike is evaluated in terms of an impact integral, which is the integration of the load over the duration of the strike.

Shown in Figures 10a through 10d are the results of a sample calculation for an AH-1G type rotor striking a 6-inch-diameter tree (pine) at zero angle of attack such that the tree trunk intersects the rotor plane perpendicularly. Figures 10a through 10c are calculations for parametric variations. Tip speed is seen to be the most important parameter. The higher the tip speed, the lower the impact integral, which implies less local damage.

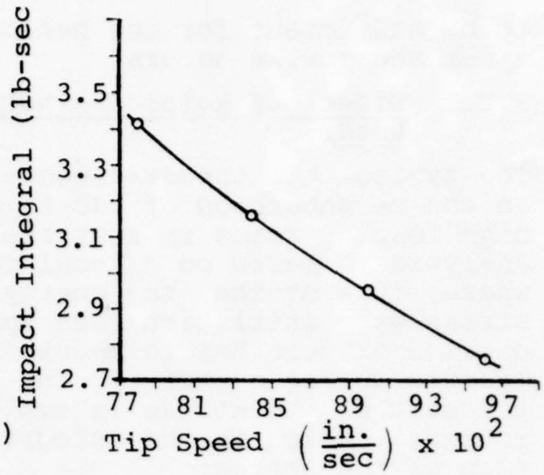
The dynamic response to the strike loads can ideally be calculated by using NASTRAN transient response analysis. An attempt was made at calculating the dynamic response by using a NASTRAN blade model. The dynamic response was found to be very sensitive to the time increments chosen. When the time increments were decreased, the inertial response changed by as much as an order of magnitude. It was concluded that using the transient response will require detailed investigation of proper modelling techniques and proper selection of time intervals. Since this application of NASTRAN was planned to be preliminary, a large effort was not expended in investigating the details.

Some of the blade strike analysis conclusions were verified qualitatively during rotor impact test-stand experiments conducted under Bell Helicopter Textron independent research and development. Under these IR&D funds, the full-scale OH-58-type rotor was put on a whirl stand and tree trunks of varying diameter were propelled into the tip-path plane. It was found that at 80-percent RPM the rotor could safely chop through a 5-inch-diameter tree without any damage to the blade spar. The quantitative blade strike data from these tests will be available subsequently.

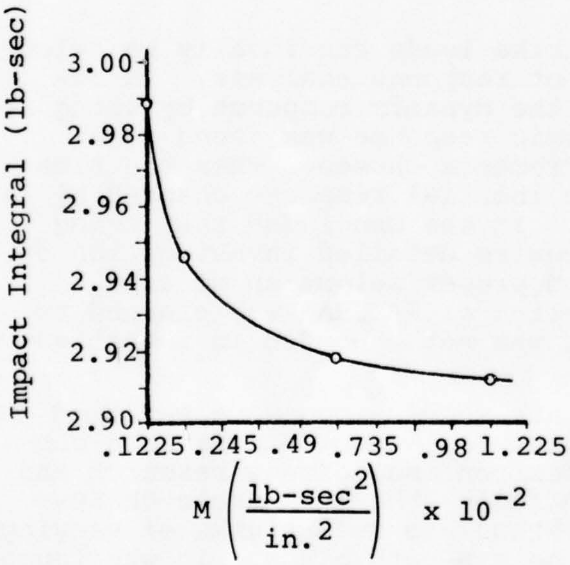
One purpose of developing the analyses mentioned above was to establish design criteria for designing the hub and the blade.



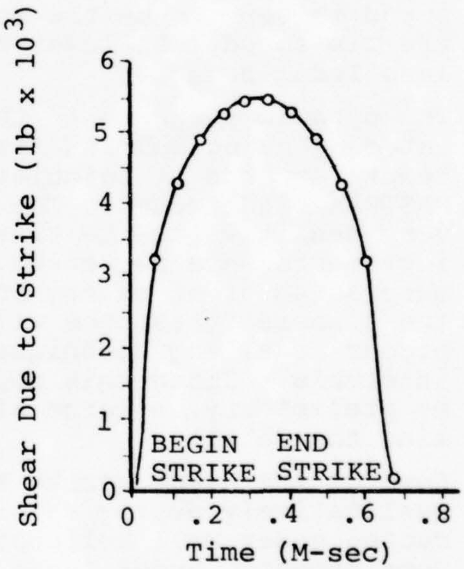
a. Impact Integral Versus Nose Radius



b. Impact Integral Versus Tip Speed



c. Impact Integral Versus Mass Per Unit Length



d. Load-Time History During Impact (Strike)

Figure 10. Sample Calculations for AH-1G Rotor Strikes

An informal survey of actual failure location was also made to aid in guiding the analysis. The most commonly encountered failure locations on main rotor blades are the mass and stiffness discontinuity points (for example, locations at the end of the tip weights, locations at the end of the doublers, blade hub grip bolts, etc.). Failures on the teetering hubs were rarely encountered.

3.2.3 Reducing Blade Replacements Due to Slight Damage

The obstacle strikes that result in mishap classes four (incidental damage) through six (precautionary landing) often result in slight damage to main and tail rotors. This slight damage is often in the form of scratches, nicks, gouges, tears, holes, etc. In the field, this type of damage is usually inspected visually. Decisions to repair or replace the blades are made based on the requirements described in the maintenance manual. (For Army Model UH-1D/H, see Reference 3.) The acceptable nicks and scratches are defined in this manual and can be locally repaired. Similarly, minor voids can be repaired locally. However, the maintenance manual recommends that main rotor blades exhibiting major damages in the following forms be condemned:

- trailing-edge holes
- nick or dents deeper than 1/8 inch
- blade bends more than 0.5 inch
- leading-edge holes through spar assembly
- skin cracks
- corrosion requiring a patch of 10 square inches or more
- hole through doublers
- void between doublers

Concepts that reduce the frequency of blade replacements due to slight damage were considered. In most cases, the implementation of these concepts required large increases in cost; therefore, this approach was not pursued further. Improvements in the area of damage tolerance, however, have taken place with the introduction of composite blades.

The use of material such as fiberglass allows the composite blades to have higher fatigue life, greater ballistic tolerance, gradual failure modes, and virtually no corrosion. In terms of damage repairability, any holes, cracks, etc., in the fiberglass blade skin and spar cause local delaminations which can be repaired easily by applying patches. Relatively large holes in the afterbody can also be repaired by applying a

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[3]TM55-7520-210-20, ORGANIZATION MAINTENANCE MANUAL FOR HELICOPTER MODEL UH-1D/H, Department of the Army, Washington, D. C., September 1971.

patch. Because of the highly demonstrated damage tolerance of composite blades, the scrap rates due to slight damage should go down dramatically.

3.3 MAIN ROTOR PROTECTION CONCEPTS

3.3.1 High Inertia Rotor System

The high inertia rotor system offers advantages over a conventional rotor system, one of which is improved ability to survive obstacle strikes without serious damage. Reference 4 showed that by increasing the rotor blade mass per unit length, the impact integral (impulse) of a blade-obstacle strike is reduced. This effect, in combination with a reduced leading edge radius, would offer an effective system for surviving blade strikes on objects such as trees. Some additional features (not related to blade strike) are as follows:

- Reduction or elimination of the height-velocity restriction (deadman's curve)

- Simplification of autorotational landing (cyclic flare eliminated)

- Performance gain from "bleed RPM" technique

- Increased NOE capability (due to stored available energy)

The high inertia rotor configuration requires additional weight (in comparison to a conventional rotor), which is distributed along the blade span. This additional mass would best be incorporated into the blade spar itself.

An experimental high inertia rotor system was developed and tested on the Model 206 (see Figure 11). The rotor blades were modified to accept tungsten tip weights (Figure 12), and a Bell experimental Model 640 hub was used. (This was an elastomeric hub design, which was stronger than the standard hub.) Tip weight was varied from 11.5 pounds to 55.0 pounds, and a weight of 41 pounds was judged to give the best overall performance. The total rotor inertia in this configuration was 172 percent of standard inertia. For a Model UH-1, the same percentage increase in rotor inertia would amount to 135 pounds of additional rotor weight (90 pounds would be the tip weight, and 45 pounds would be the beef-up of the hub structure needed to carry higher centrifugal force).

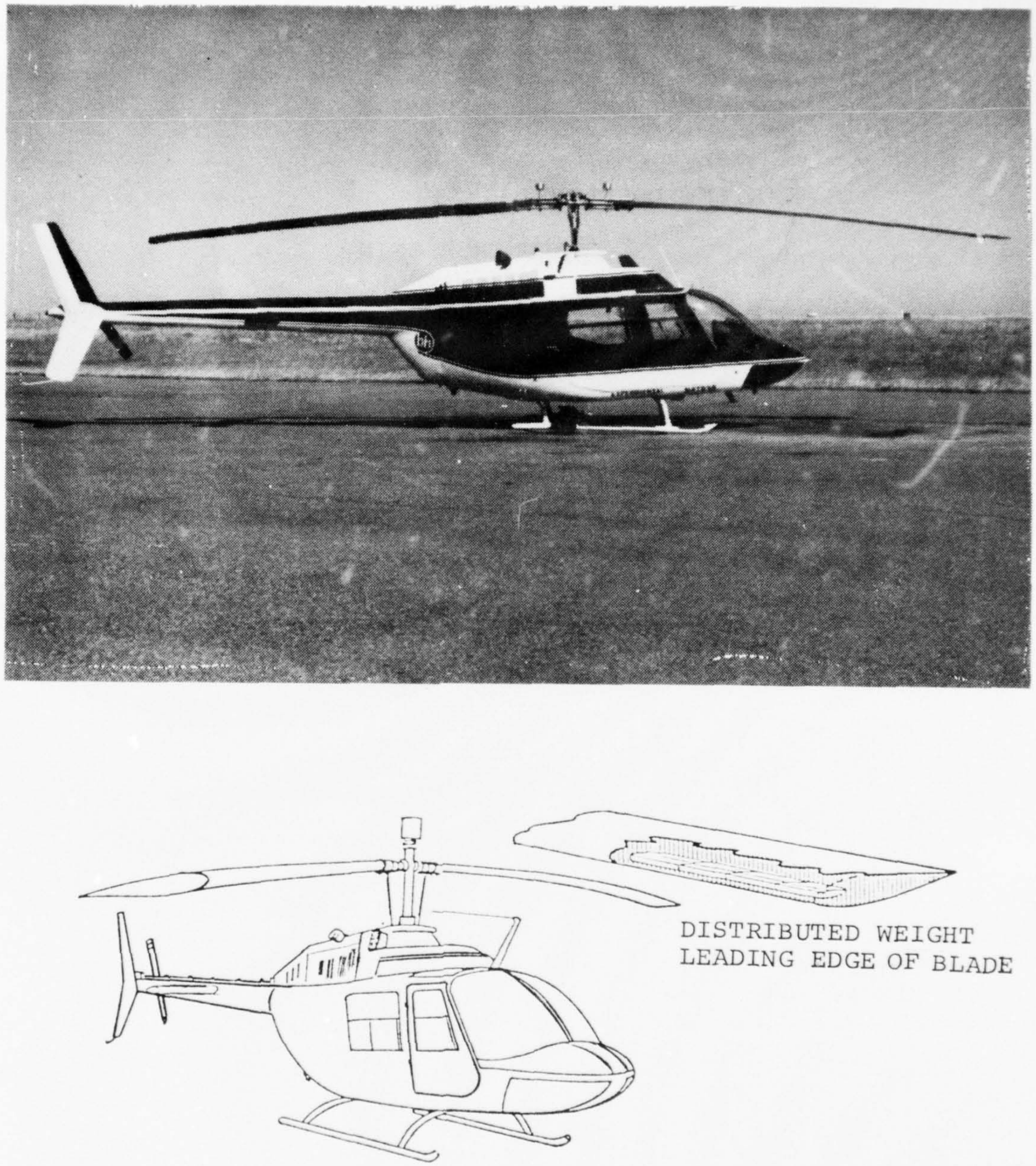

Figure 11. High Inertia Rotor, 206-Experimental Aircraft

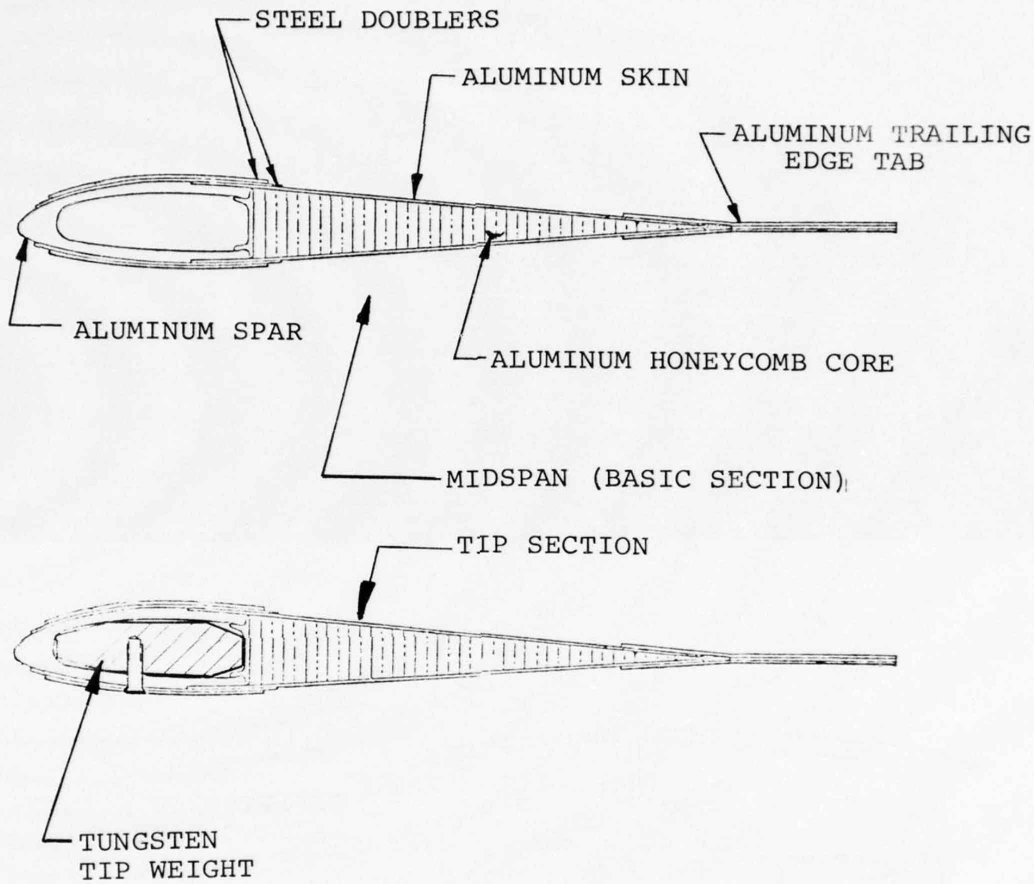

Figure 12. Model 206 High Inertia Rotor Blade Sections

3.3.2 Cutting Edge in Main Rotor Leading Edge

A cutting edge on the main rotor blade leading edge would reduce the impact integral associated with blade strikes and facilitate the severing of wire and wooden obstacles. The reduction in impact integral would be due to reducing the leading edge radius (Reference 4). Two possible configurations exist for this concept:

- A cutting piece is hidden in the leading edge (Figure 13) and covered with a filler and abrasion strip.
- A sharp leading edge is incorporated into the basic blade section.

In each of the above concepts the sharp leading-edge tip member would also serve as a balance weight. Additionally, this concept lends itself well to combining with the high inertia rotor concept.

No significant structural or loads problems would be created by this concept.

3.3.3 Pyrotechnic Obstacle Cutter in Blade Leading Edge

A pyrotechnic system developed for protection of the main rotor blades uses segments of linear shaped explosive charges along the blade leading edge (Figures 14 and 15). These 8-inch-long shaped charges cut the wire upon impact. The system is battery powered, but can also be energized through slip rings. By locating several charges along a blade spar, protection is provided against multiple strikes.

When a wire is hit and cut by the blade, the protective cover over the explosive charge is blown away. The structural integrity of the blade is not damaged during detonation, and the blades can be repaired and new charges installed at a maintenance depot. Tests have been performed on all the individual components of this type of system. The overall system response time is kept below 30-40 μsec through the use of exploding bridge-wire detonators. The system will be capable of being checked during preflight inspection to guarantee the performance of the detonators and electrical system. A charge as large as 600 grain/ft RDX explosive can be installed in the blade leading edge for protection against the 1.1-inch-diameter aluminum cable steel reinforced (ACSR) power line. The shaped charges, by penetrating up to 6 inches deep in oak, improved

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[4] Gupta, B. P., BLADE STRIKE, Bell Helicopter Textron Inter-Office Memo 81:BG:ek-8094, September 1976.

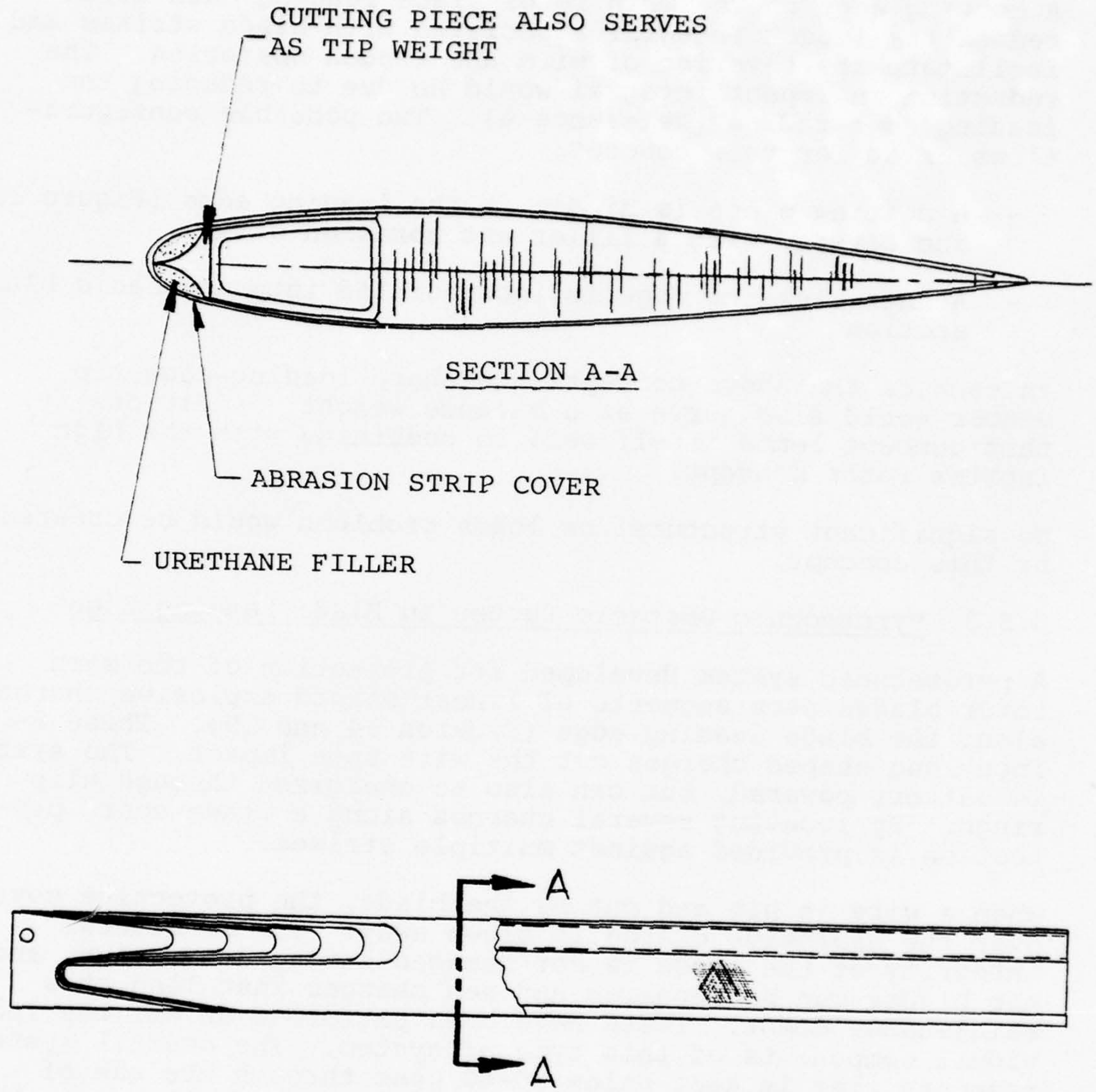

Figure 13. Mechanical Cutter Hidden in Rotor Leading Edge

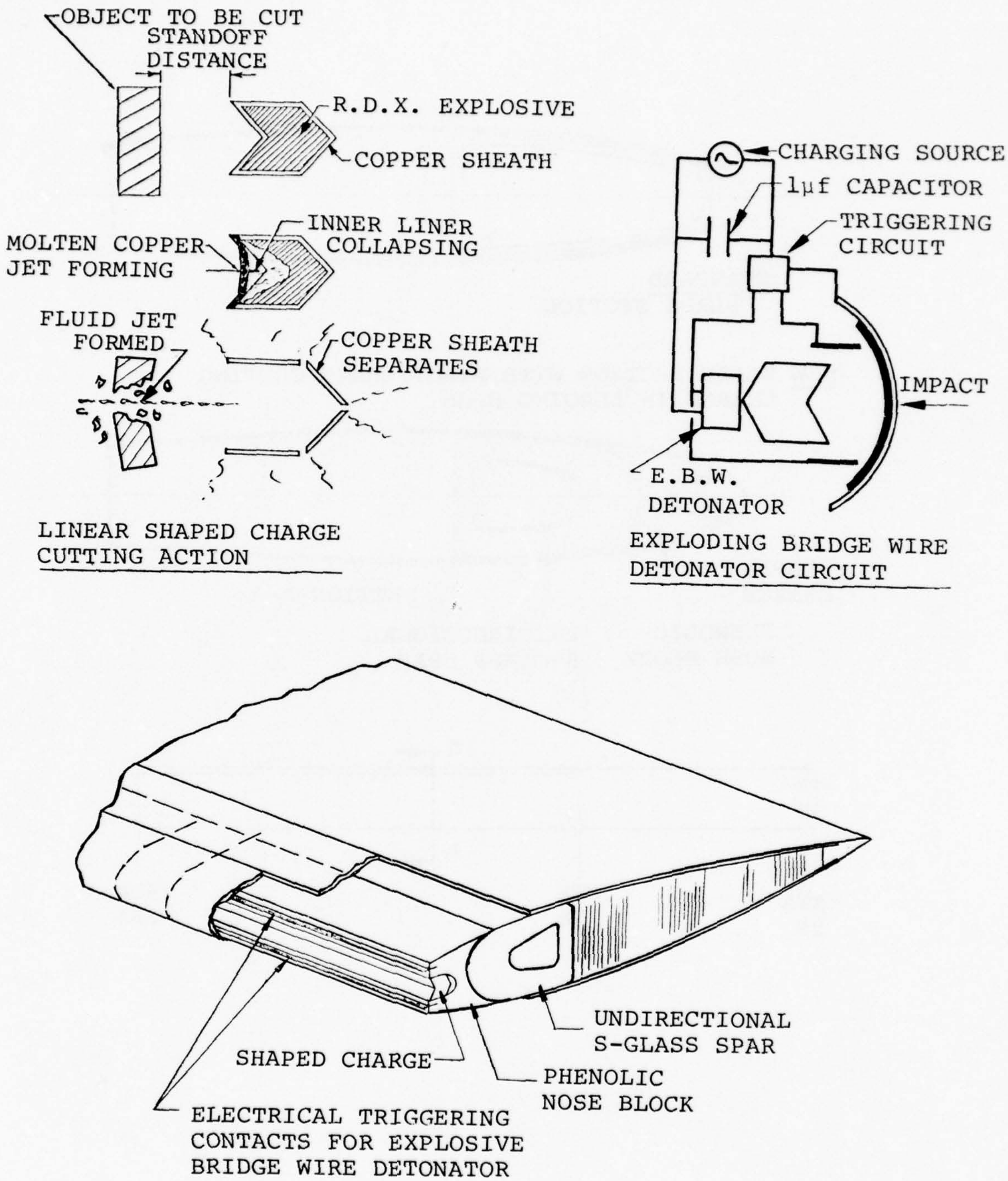

Figure 14. Pyrotechnic Obstacle Cutter in Blade Leading Edge

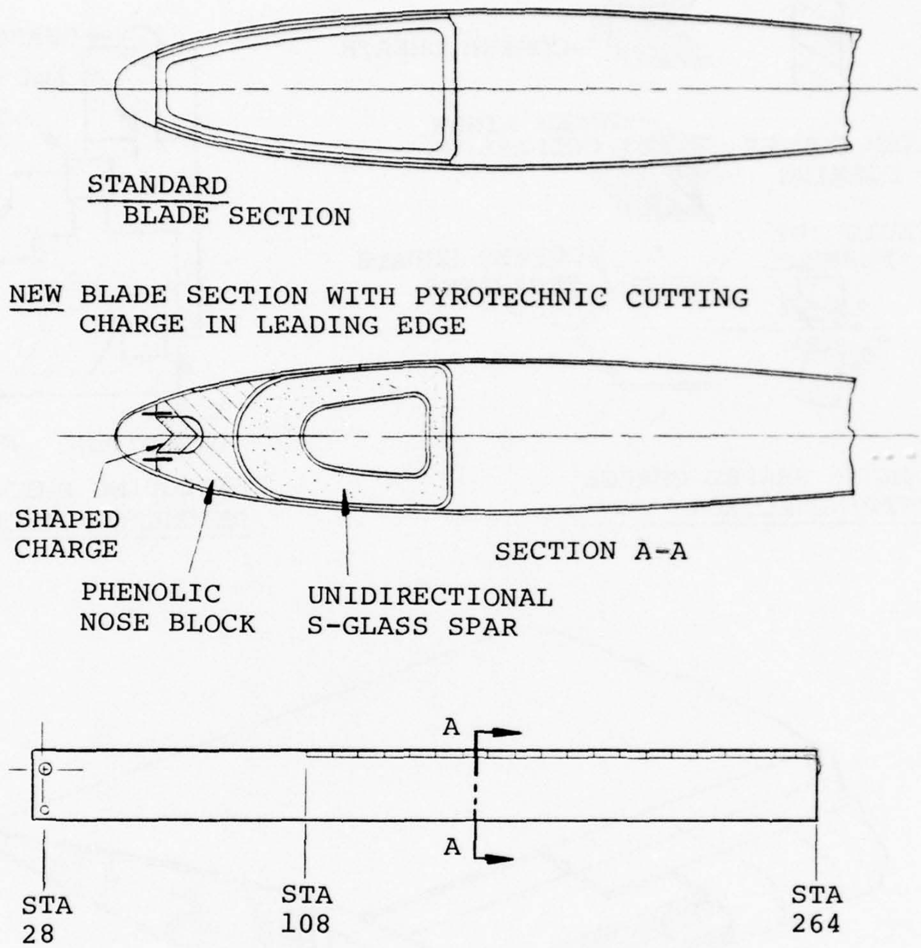

Figure 15. Pyrotechnic Cutters in Composite Blade Leading Edge

the blade's ability to cut through wood. The shrapnel and noise of the system will not affect the safety of the pilot or crew.

The size of the shaped charge will be between 300 and 600 grains per foot depending on the exact type of wires expected to be cut. The shaped charge system can be adapted to an existing blade or built into a newly designed blade. The electrical equipment, including batteries, capacitors, and charging circuit will weigh about 25 pounds. The shaped charges, holders, detonators, and covers will weigh approximately 45 pounds per ship set for a Model UH-1 type aircraft. The total system weight will be approximately 23 pounds per blade, some of which can be offset by reducing the amount of inertia weight used in the blade. A system weight breakdown is shown in Table 5. The details of a pyrotechnic obstacle cutter in the blade leading edge is described in Reference 5.

3.3.4 Shrouded Main Rotor - "Velkoff" Ring

The Velkoff rotor system (Reference 6 and Figure 16) was conceived for the purpose of improving vibration characteristics of helicopter rotors. In addition to the operational and vibrational improvements sought, the Velkoff rotor would also be effective as a rotor shroud for obstacle strike protection.

The Velkoff rotor employs a ring attached to "spokes" that run radially through the blades from the hub to the ring. The blades then pivot about the spokes to change pitch. The effect of the ring in preventing blade strikes would be to deflect some portion of obstacles from entering the rotor disc. This would be most effective against slack wires, less effective against rigid obstacles and high tension wires, and ineffective against airborne debris.

Reference 6 discusses some performance trade-off studies (aside from strike protection) involved with this concept. The drag at the rim was found to be significant, but the study indicated that this would be a competitive concept if many lightweight blades could be used. Other negative aspects of this concept include high weight penalty, reduced agility, high ring-bending stresses due to CF, typical low frequency inplane "windup" mode (.5 to .7 Hz), and ring buckling under

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[5]Reyes, P. A., WIRE STRIKE PROTECTION STUDY, Bell Helicopter Textron Report 599-341-900, April 1977.

[6]Velkoff, H., MULTIBLADED RING ROTOR DESIGN, Presented at the 29th Annual National Forum of the American Helicopter Society, May, 1973.

TABLE 5. WEIGHT BREAKDOWN FOR MODEL UH-1 SYSTEM

	Weight Each	No. Reqd.	Total Weight-lb
Shaped charges	300 grain/ foot .28 lb	40	11.2
Detonators	.037 lb	80	3
Wire	.018 lb/ft	160 ft	3
Batteries	2 lb	2	4
Capacitor	3 lb	2	6
Circuitry	.5 lb	2	1
Covers	.015 lb	40	6
Miscellaneous	1 lb	2	2
Holders	.22 lb	40	8.8
Total weight per ship set			45.0 lb

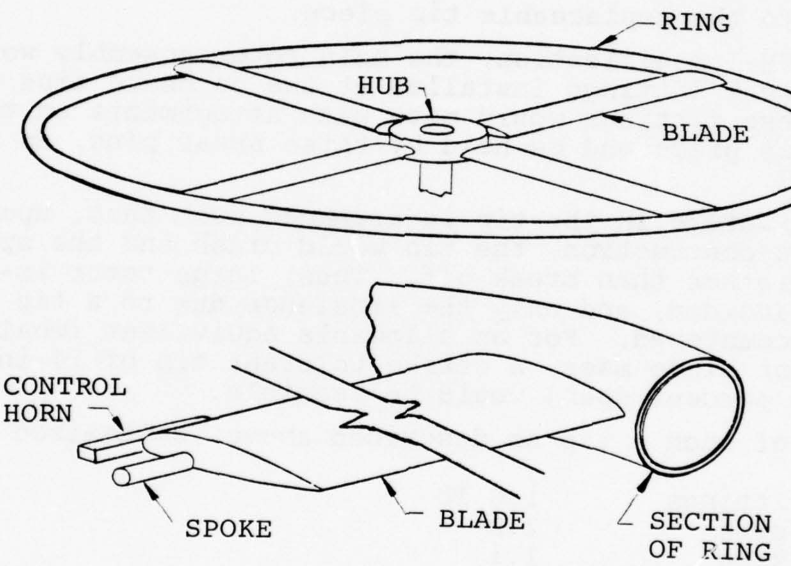

Figure 16. Shrouded Main Rotor; Velkoff Type

static ground conditions. On the positive side, blade fatigue life is improved since shears are reacted through the radial spokes, and the spokes can also carry loads when blades are damaged.

The conclusion of Reference 6 was that this could be considered a realistic tail rotor concept because of the improved performance on high disc-loaded rotors. In view of these assessments, it is concluded that this is not a viable concept for main rotor strike protection.

3.3.5 Strike-Tolerant Main Rotor Tip

The strike-tolerant main rotor tip would allow the tip to strike rigid obstructions without causing significant rotor imbalance and the consequent vibrations, high loads, and possible loss of control. Damage due to tip strike only would be limited to the replaceable tip piece.

As a Model UH-1 modification, the main rotor assembly would have attachment fittings installed at the outboard tips of the blades. These fittings would mate with attachments on the crushable tip piece and be held by three shear pins, as shown in Figure 17.

The spar structure in the tip is arranged such that, upon impacting an obstruction, the tip would crush and the spars would fold rather than break off. Thus, large rotor imbalance is avoided, and only the imbalance due to a tip c.g. shift is encountered. For an allowable equivalent imbalance of .5 percent blade mass, a strike-tolerant tip of 14-inch length (2.4 percent span) would be feasible.

The weight of such a tip as described above is itemized below:

Fittings	1.0 lb
Spars	2.2
Skins	1.1
Trailing edge	.6
Leading edge	.8
Foam filler	.5
	6.2 lb

Note that the overall rotor weight should remain unchanged by this modification since tip inertia weights can be removed from the basic blade.

3.3.6 Coaxial Rotors

One example of coaxial rotors is the Advancing Blade Concept Rotor. This concept is being flight tested by Sikorsky Aircraft under a contract from the U.S. Army.

The concept employs two coaxial, counterrotating, very stiff hingeless rotors. The purpose of the concept has been to eliminate the rotor blade stall and provide greater speed and agility.

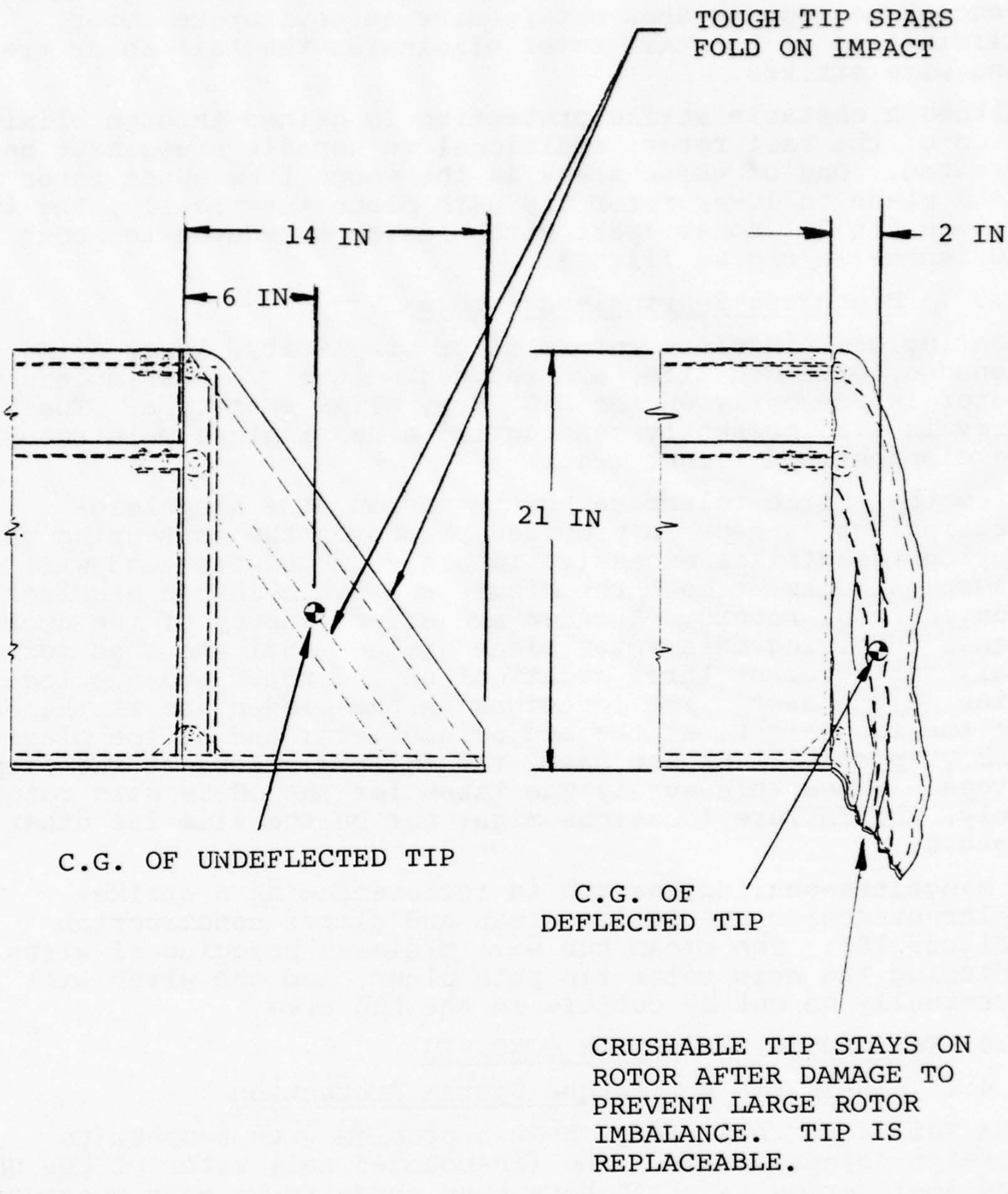

Figure 17. Strike-Tolerant Main Rotor Tip

Because of the counterrotating rotors, the advancing blade concept helicopter does not require an antitorque rotor. Elimination of the tail rotor eliminates the tail rotor tree and wire strikes.

Although obstacle strike protection is gained through elimination of the tail rotor, additional vulnerable areas have been created. One of these areas is the space from upper rotor tip path plane to lower rotor tip path plane (statically, the two rotors are 30 inches apart with clearance reduced to about 20 inches in cruise flight).

3.3.7 Hingeless-Bearingless Rotors

Bearingless-hingeless rotors offer simplicity, lower maintenance, extended life, and reduced weight. A bearingless tail rotor is presently on the U.S. Army UTTAS prototype. The U.S. Army is also presently contracting a bearingless main rotor development and flight test.

From the strike tolerance point of view, the hingeless-bearingless concept is proposed, based on the contention that during the strikes excessive impulsive chordwise load will cause failures at both the hinges and pitch-change bearings in conventional rotors. A cause-and-effect survey of the accidents involving main rotor blade strikes indicate that most failures occur at three locations on the rotor and one location on the mast. The locations on the blades are at the end of the tip weight, at the end of doublers, and at the blade-hub grip bolts. On the mast, the failure occurs at the flap stops. Since this survey was taken for the OH-58 main rotor only, the failure locations might not be the same for other rotors.

A hingeless-bearingless hub is recommended as a strike-tolerant design due to its clean and simple construction (Figure 18). The clean hub will minimize snagging of wires entering the main rotor tip path plane, and the wires will eventually be cut by cutters in the hub area.

3.4 TAIL ROTOR PROTECTION CONCEPTS

3.4.1 Fan-in-Fin Antitorque System Protection

The tail rotor has always been a problem with respect to foreign object damage. The fin-mounted tail rotor of the UH-1 and AH-1 series aircraft have been shown to be more susceptible to wire strikes than the boom-mounted tail rotor of the Model OH-58A. This is because the high tail rotor has a larger exposed area for potential strikes from behind and above. When the Model UH-1 flies in a cruise attitude, the tail rotor is at times higher than the top of the main rotor tip path plane. Also, the vertical fin on the Model OH-58 shields the tail rotor from wires.

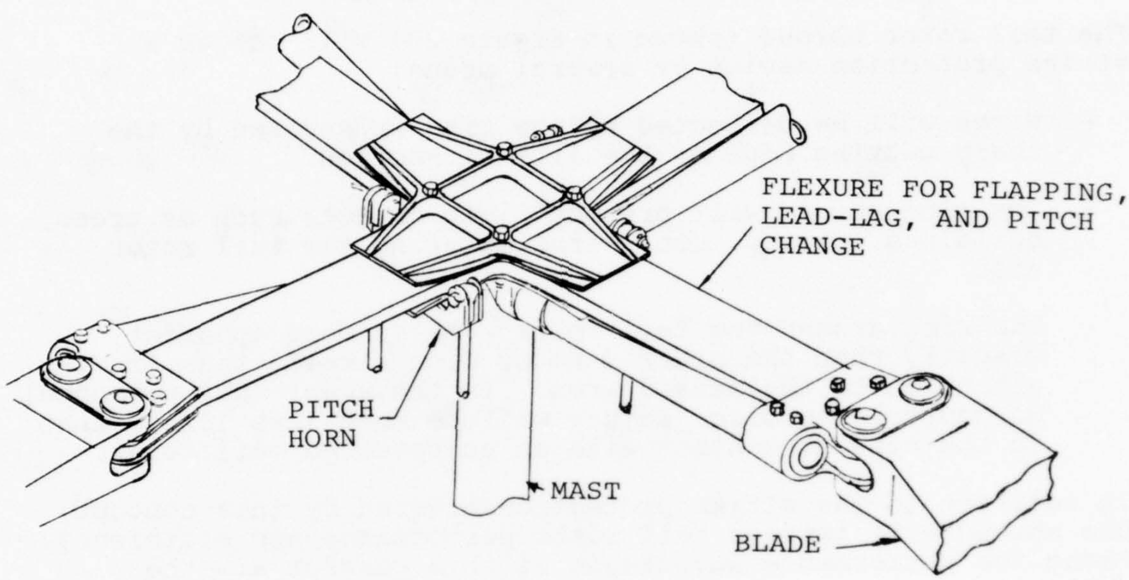

Figure 18. Bearingless-Hingeless Main Rotor Hub

One scheme that offers a substantial improvement in wire strike protection with current state-of-the-art technology and minimum complexity is the fan-in-fin (Figure 19). The fan is smaller in diameter than a corresponding conventional tail rotor. The blades are completely protected by the cowling. The fan-in-fin requires more hover horsepower than the standard tail rotor, but less power during cruise. Table 6 summarizes the differences between a conventional tail rotor and the fan-in-fin.

3.4.2 Tail Rotor Shroud/Thrust Ring/Vertical Fin

The tail rotor shroud (shown in Figure 20) will act as a strike protection device by several means:

- Wires will be deflected by the ring or severed by the sharp cutting edge of the airfoil section.

- The ring shroud will prevent rigid objects such as trees, buildings, ground, etc., from entering the tail rotor disc.

- The ring around the tail rotor will be more apparent visually than the blurred rotor disc itself, thus drawing attention to the hazard area. In the event that personnel do contact the disc, injury will be much less likely than in the case of contact with an unprotected tail rotor.

In addition to the strike protection offered by this concept, the shroud will improve tail rotor performance and efficiency. Among the performance advantages of this concept are the following:

- When properly configured, the blade tip vortex produces a thrust on the ring shroud. This is a mechanism for increasing the static thrust of a rotor by up to 25 percent of its basic free air value.

- The improved rotor efficiency allows the envelope of the shrouded configuration to be the same diameter as the basic tail rotor configuration and gives the same thrust for comparable power.

- The surface area of the shroud is typically more than required for yaw stability; i.e., the normal vertical fin may be removed and stability will be as good as or better than before.

- A conventional tractor-type tail rotor blows air against the vertical fin; this fin load reduces the overall

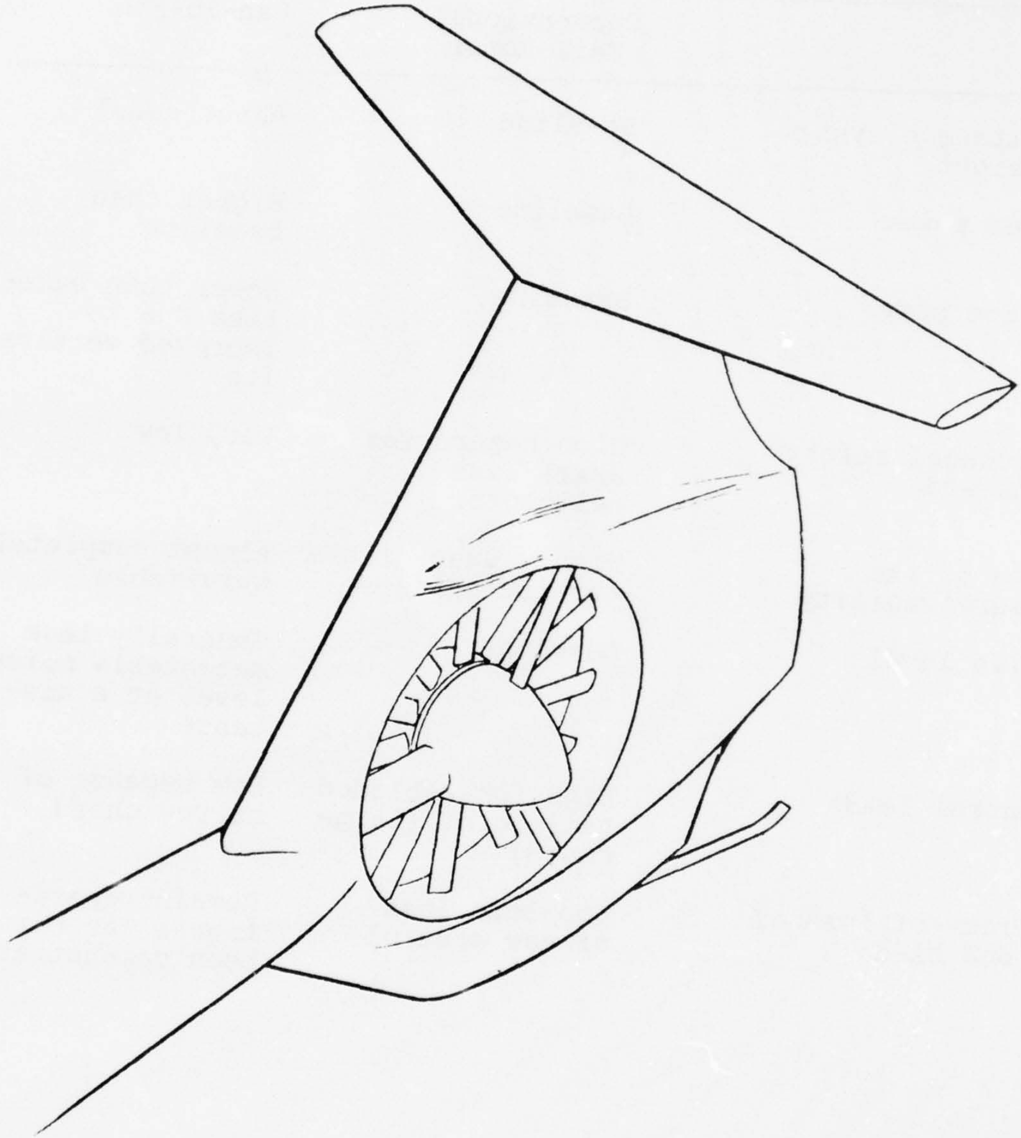

Figure 19. Fan-in-Fin Antitorque System

TABLE 6. CONVENTIONAL TAIL ROTOR AND FAN-IN-FIN COMPARISON

	Conventional Tail Rotor	Fan-in-Fin
Antitorque system weight	Baseline	About equal
Hover power	Baseline	Higher than baseline
Cruise power	Baseline	Lower than base-line due to improved vertical fin
Personnel safety hazard	High hazard for small size helicopter	Very low
Wire strike survivability	Highly susceptible to wire strikes	Almost completely survivable
Noise level	Baseline	Generally less detectable noise level at a dis-tance
Control loads	High for 2-bladed tail rotor (large chord)	Low because of narrow chord
Effect of loss of one blade	Complete loss of yaw control	Remains opera-tional (as has been demonstrated)

TAIL ROTOR SHROUD WITH SHARP (KNIFE EDGE) OUTER EDGE. AIRFOIL CROSS SECTION PROVIDES THRUST FROM T/R RADIAL WASH. ALSO REPLACES VERTICAL FIN.

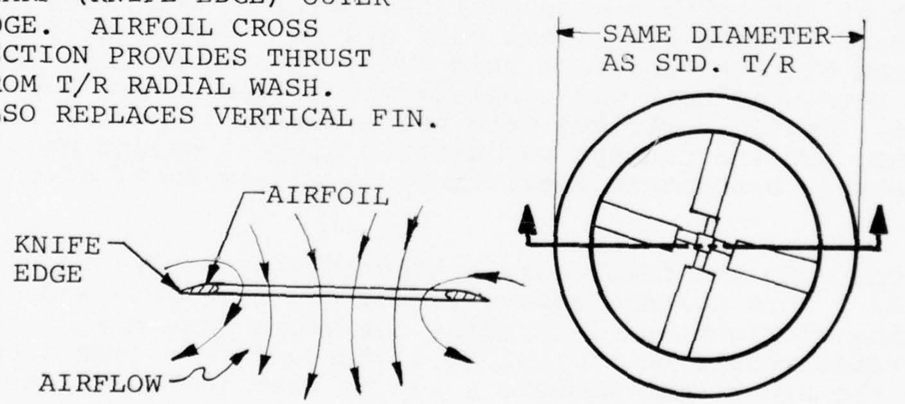

Figure 20. Tail Rotor Shroud/Thrust Ring/Vertical Fin

thrust that the tail rotor can generate. A pusher-type tail rotor will experience some reduction in thrust due to the upstream blockage from the vertical fin. The shrouded tail rotor concept eliminates the vertical fin and the associated blockage and sideload penalties.

Weight and cost of the tail rotor shroud should be only slightly greater than the vertical fin which it replaces.

This concept offers the potential combination of a guarded tail rotor system with improved yaw stability and antitorque performance.

3.4.3 Main Rotor Protection Concepts for Tail Rotor Applications

The following main rotor concepts were also considered for tail rotor applications:

- Strike-tolerant tips
- Hingeless-bearingless tail rotor
- High inertia tail rotor with sharp leading edge

3.5 HELICOPTER FUSELAGE PROTECTION

3.5.1 Retractable Skid Landing Gear

A retractable landing gear would offer shielding of the landing gear system from direct obstacle strikes. Only the protective fairings (if required) would be susceptible to an obstacle strike.

One type of retractable skid gear was designed and flown on a Model AH-1G (Figure 21). This gear system offered independent retraction of right and left skid tubes (for slope landings), and the retracted gear was completely enclosed within the fuselage. Obstacle strikes were not a design consideration at that time, and the concept was dropped since a weight penalty of 235 pounds brought an improvement in cruise speed of only 6 knots.

An alternate to the completely retractable system is shown in Figure 22. This system, however, does not have independent retraction of right and left skids for slope landings. The configuration would be similar to a standard skid gear system in that the cross tube members would be used for energy absorption. Pin joint connections would be located at the cross-tube-to-skid tube junctions, and an actuator would rotate the cross tubes causing the gear to fold along the side of the lower fuselage and into protective fairings. By keeping the

Figure 21. Flight Test of Retractable Skid Landing Gear on AH-1G

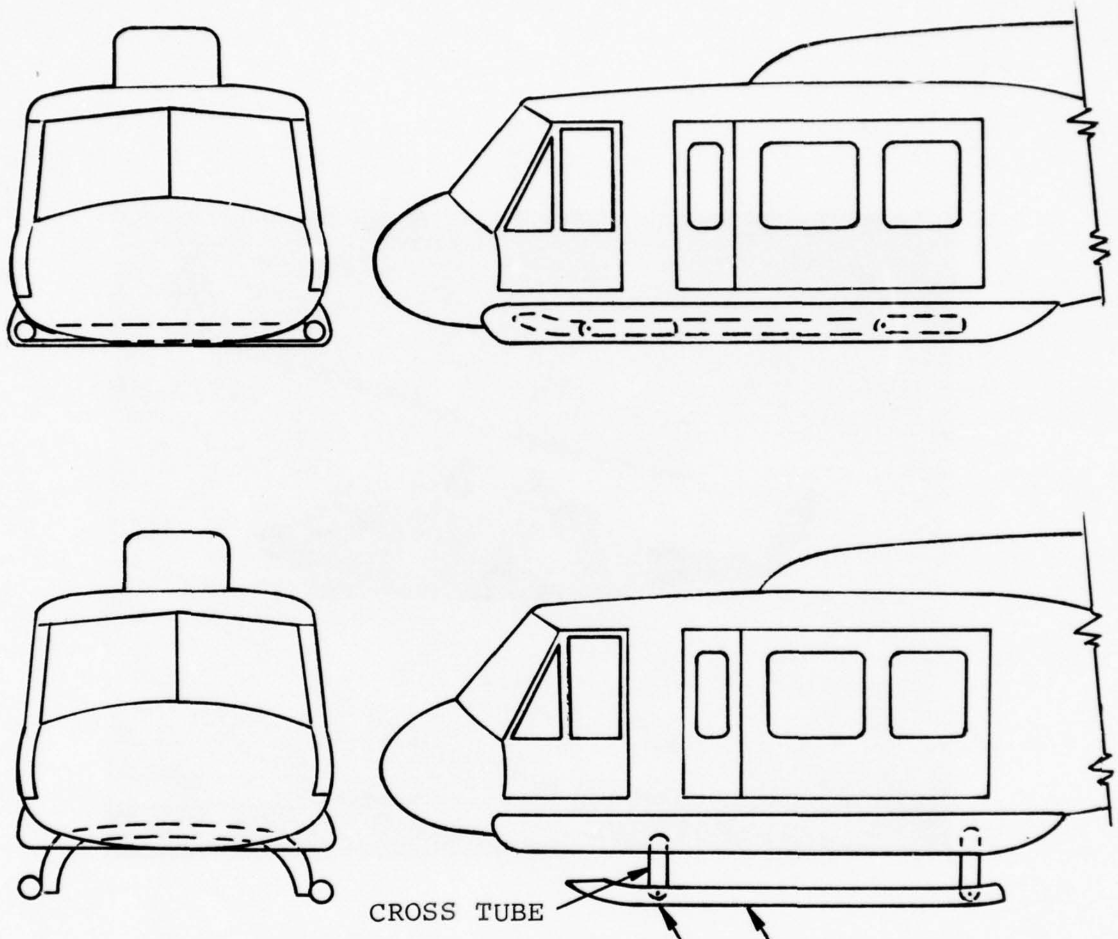

Figure 22. Retractable Skid Gear

crosstubes as the energy absorbing members, very minor structural modification would be required to support the landing gear loads. A weight estimate for the additional items required in this concept is given below:

Crosstube support bearings (4 @ 2 lb)	8 lb
Crosstube-to-skid tube pin joint fittings (4 @ 5 lb)	20 lb
Hydraulic actuators (2 @ 10 lb)	20 lb
Fairings	5 lb
	53 lb

3.5.2 Faired-in Skid Landing Gear

The skid landing gear could be protected from entanglement with suspended wires and cables by eliminating the forward protruding skid tube (Figure 23), or by placing fairings on the standard skid gear (Figure 24).

The first concept would be more desirable but would probably be feasible only on a new aircraft design. This is due to the required support structure and geometry to give acceptable rollover stability. (Existing designs would require extensive modifications to provide these features.)

The second concept (add-on fairings) could be developed into a kit. The fairings would be flexible in the lateral directions to allow deflection with the gear on landings, but they would be stiff in the vertical direction to assure that wires would be deflected rather than snagged by the fairings. Drag and pitch stability would be affected by the fairings. The extent of these effects has not been determined, but it is assumed that they would be small.

3.5.3 Deflector Shield on Wheeled Landing Gear

A deflector shield on a wheeled landing gear may be incorporated into a wing/landing gear system such as shown in Figure 25. This is an integrated wing/landing gear design in which the outer portion of the wing, which encloses an oleo strut, folds down for absorbing landing and ground handling loads.

As an obstacle deflector, the shield (wing surface and internal structure) has a smooth surface that would not easily snag wires. Also, the landing gear does not protrude down beneath the fuselage as does the standard skid gear. This should reduce the likelihood of a wire striking the lower fuselage and causing large pitching moments and the associated loss of control.

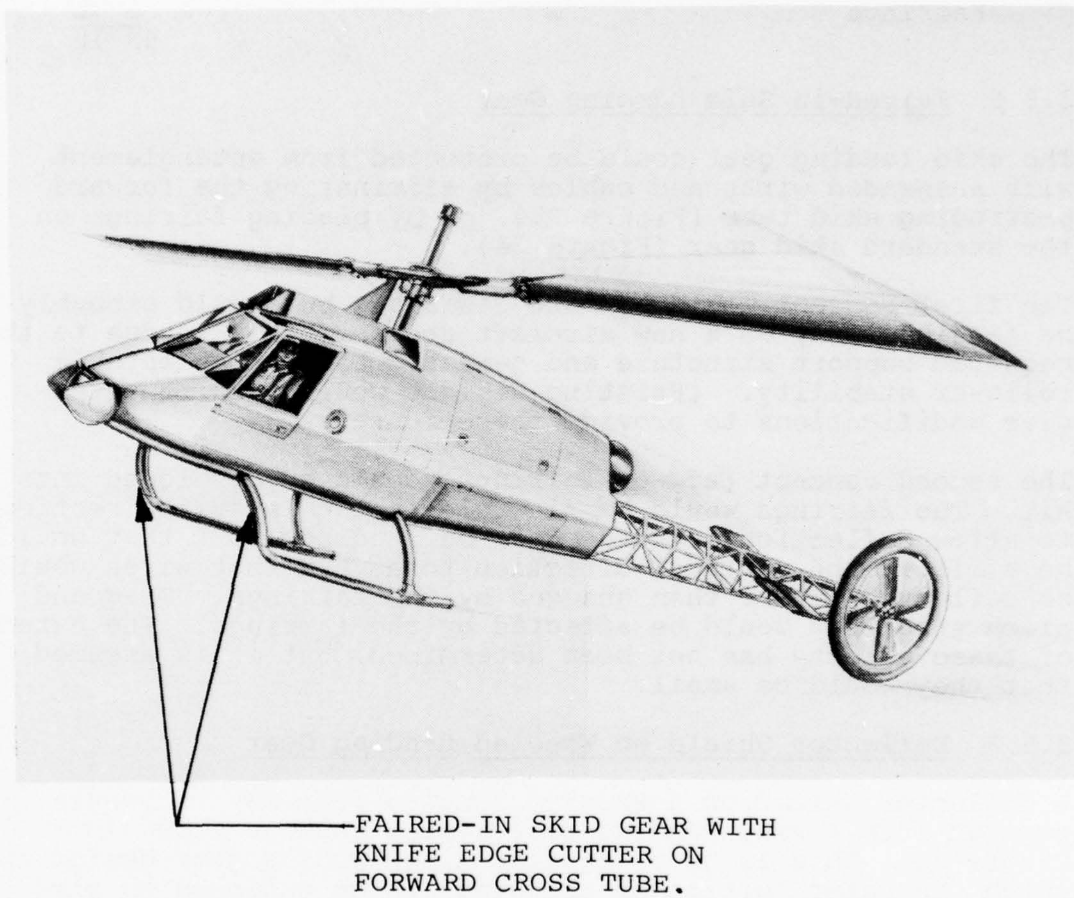

Figure 23. Faired-in Skid Landing Gear

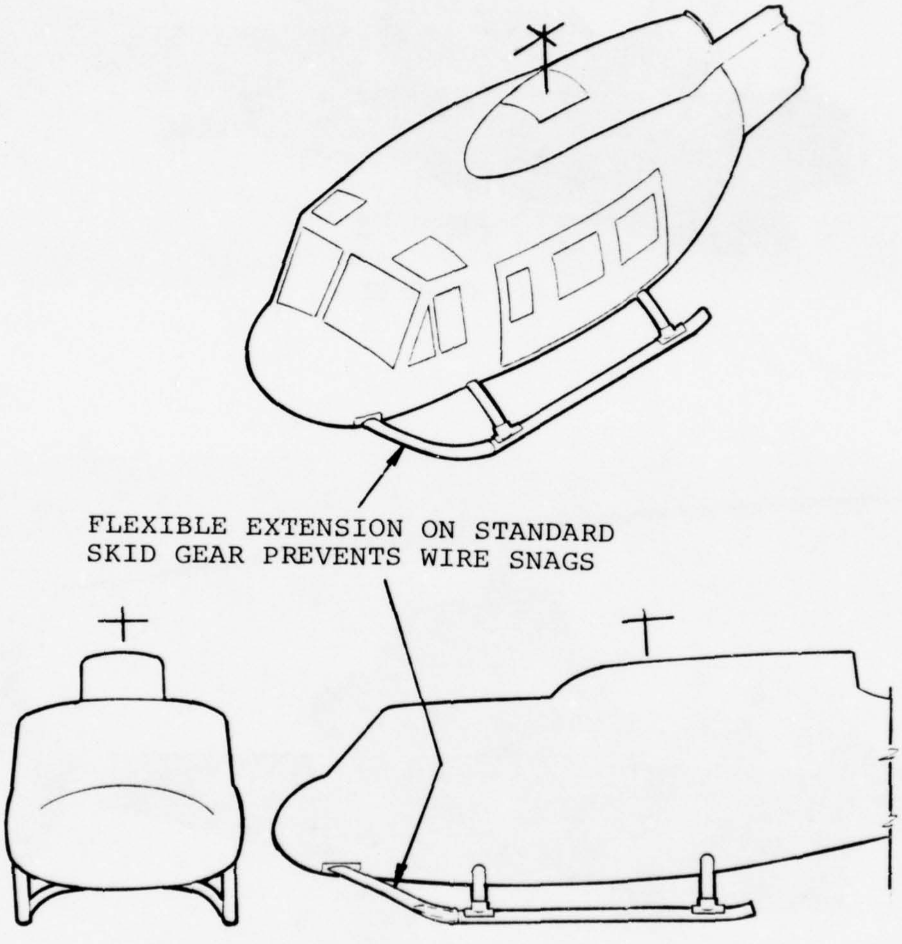

Figure 24. Faired-in Skid Landing Gear (UH-1D Modifications)

a) GEAR UP

b) GEAR DOWN

Figure 25. Deflector Shield on Wheeled Landing Gear (Shown on Model AH-1)

At BHT, a design study was conducted in 1971 to determine the feasibility of using this concept on an AH-1J helicopter (Figure 25). The performance benefits cited by that study were as follows:

- Allowable landing sink speed was approximately doubled
- Wing lift during maneuvers was increased by about 3000 pounds
- Allowable store weight on the wing pylons was increased to about 1000 pounds
- Roll control in low "g" flight was improved
- Ground taxi and rolling takeoffs became feasible
- The payload increase was about 250 pounds: wing lift (500 pounds) minus weight penalty (250 pounds)
- Rollover protection was improved

This type of system would be more difficult to adapt to a Model UH-1 type aircraft, but it will be considered for some future designs. The Model AH-1J study was preliminary; a more complete substantiation of the performance estimates is required if the concept is to be pursued.

3.5.4 Pyrotechnic Obstacle Cutter On Landing Gear Crosstubes

Pyrotechnic cutters on the landing gear crosstubes have been considered as a means of protecting the landing gear from obstacle strikes and wire entanglements. The linear shaped charges and detonation system are similar to those described for use on the main rotor leading edge. The arrangement of the charges on the crosstube is shown in Figure 26. This would be an effective system for protecting against high-tension wires and similar hazards but would be less effective against most other types of strikes. There would also be a safety hazard associated with locating explosive charge cutters in an area of high personnel activity. (People often step on the crosstubes to board the ship.) Although the system would not present a hazard when disarmed, it may be difficult to assure that it would always be disarmed when personnel are near the charges.

This system would be a feasible retrofit, but the inherent safety hazards make this an undesirable concept at this time.

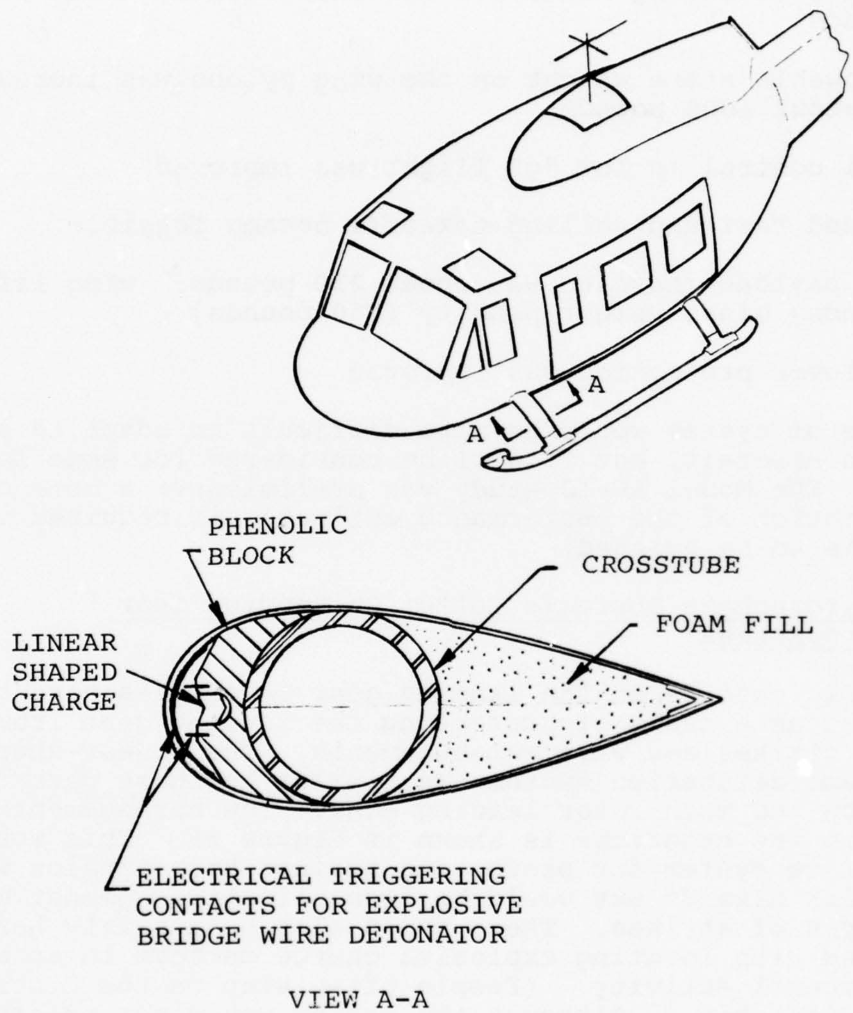

Figure 26. Pyrotechnic Obstacle Cutter on Landing Gear Crosstube

3.5.5 Wire Guides and Knife-Edged Cutters

The fixed system tolerance to wire strikes and entanglements may be improved by the use of deflectors and knife-edged (or abrasive) cutters.

Figure 27a shows knife-edged cutters located on the aircraft's nose and canopy. These cutting edges will sever a portion of the wires and cables that strike the aircraft and have some initial tension (such as strung communication cables or high-tension wires). This type of cutter has long been used and proven effective on agricultural aircraft. Also shown are wire guides for the skid gear and horizontal fin. These guides are provided to deflect wires that might otherwise become entangled with the aircraft.

Figure 27b shows the knife-edged cutter protection installed on the nose, canopy, skid gear crosstube, and outer periphery of a tail rotor thrust ring.

An abrasive cutting surface on wire guides is shown in Figure 28. The abrasive cutter might consist of carbide particles bonded to the wire's surface. This would be desirable for applications in which the wire guides are used to deflect obstacles into a cutting device (as shown in Figure 28). By providing the abrasive cutting action on the guides, the mechanical wire cutting device (guillotine, explosive charges, or similar) would not have to be triggered (or detonated) to cut small wires if these wires are cut by the abrasive guides.

Each of these concepts have potential for being retrofitted to existing aircraft. No major structural modifications would be required.

3.5.6 Retractable Wheel Landing Gear

Wheeled landing gears are being used on some new Army helicopter systems. Retractable wheel landing gears are usually retracted by using hydraulic actuators. Oleo struts are used to take the landing loads. Normally, weight penalties are associated with the use of wheeled landing gears, compared to the usual skid gears. However, on the positive side, wheeled landing gears provide improved protection during high sink-rate crash landings and sometimes against rollover. A retractable wheel landing gear is as shown in Figure 29.

The use of retractable wheel landing gears should prevent inflight wire snags by this component.

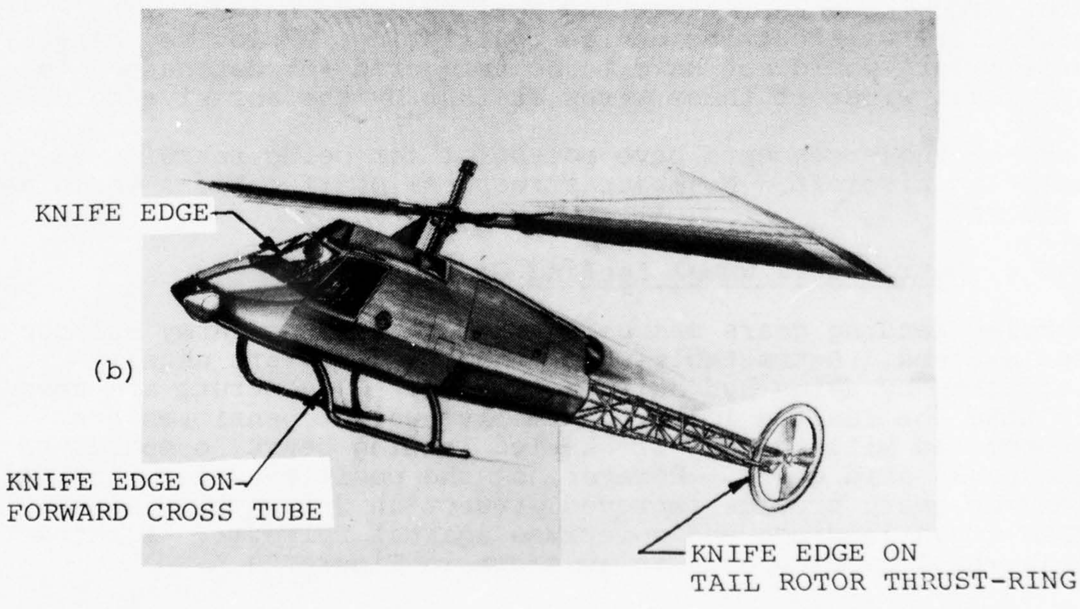

Figure 27. Wire Guides and Knife-Edged Cutters

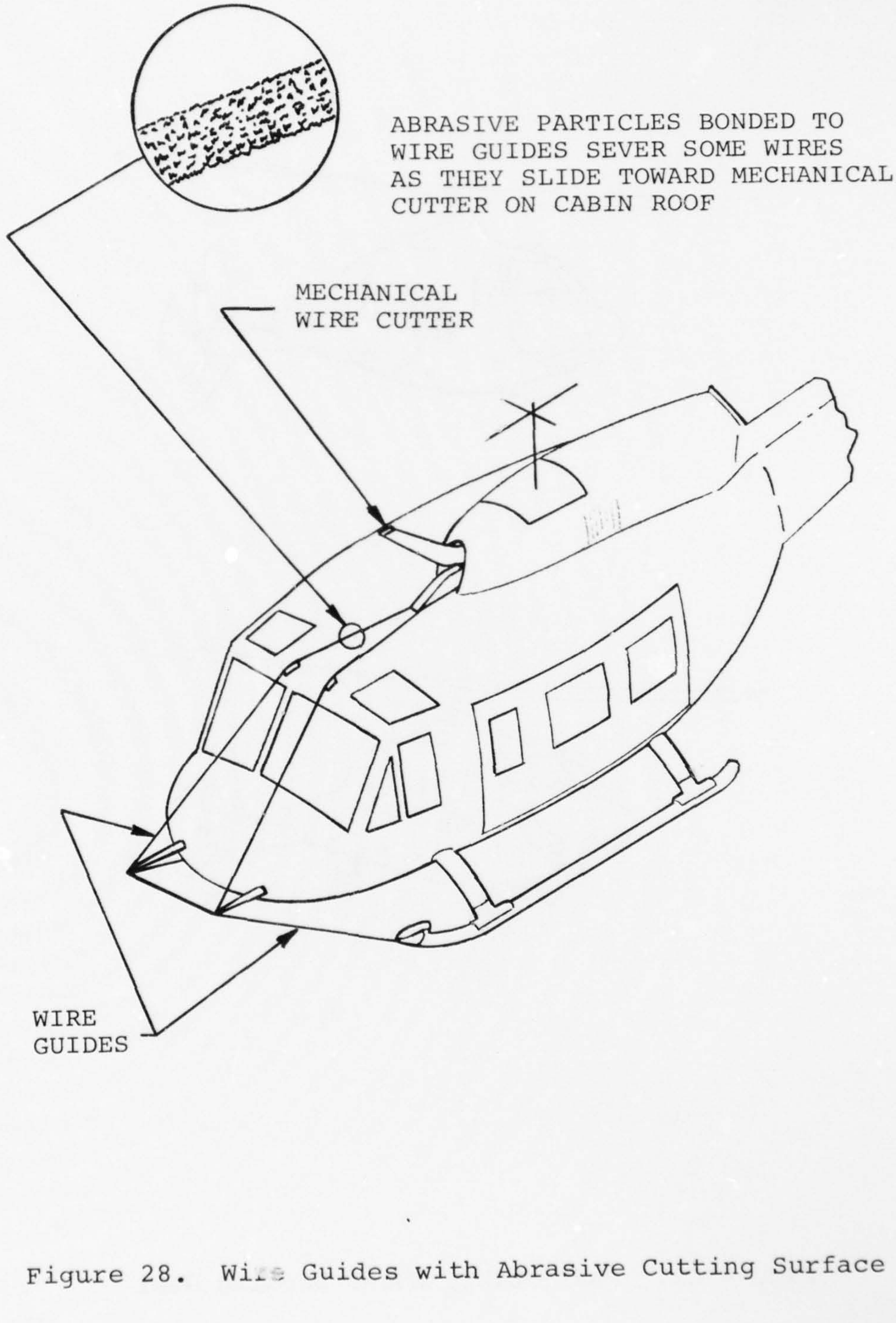

Figure 28. Wire Guides with Abrasive Cutting Surface

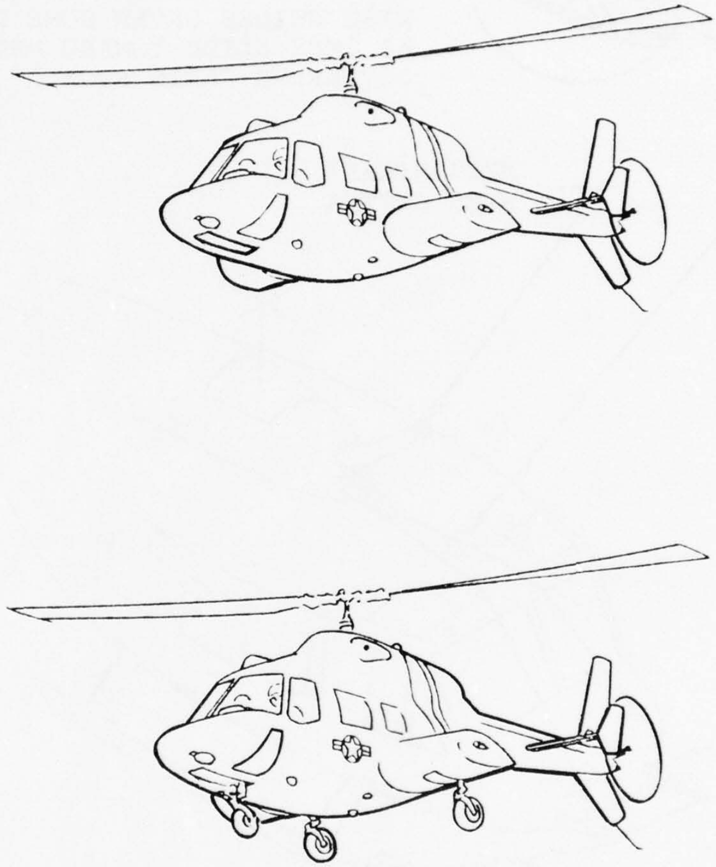

Figure 29. Retractable Wheel Landing Gear

3.6 MAIN ROTOR HUB AND CONTROLS PROTECTION

3.6.1 Linear Shaped Charge Wire Cutter for Canopy and Controls Protection

The linear shaped charge wire cutter (Figure 30) uses pyrotechnic cutting charges to sever wire obstacles. The device is mounted on the cabin roof (Figure 31) and wires are directed into the cutter by guides. Multiple wires may be cut.

The cutting device consists of a disc with linear shaped explosive charges mounted on its periphery. Guides deflect wire obstacles to an exposed charge on the disc, and the charge is detonated when contact is made between the wire and the disc. The charges and detonation system (exploding bridge wire) are similar to those described for main rotor blades (Section 3.3.3). After a charge is exploded, the disc will automatically rotate to expose a fresh charge. This provides the capability to cut several wires and also the ability to detonate several charges if required to cut a single wire or cable.

The wire cutter assembly would bolt directly onto the center roof beams. No major structural modifications would be required. Weight of the entire unit should be less than 20 pounds.

3.6.2 Internal Mast Controls

Internal mast control systems offer the advantages of shielded controls plus a very compact and low drag profile. A major wire threat has been the wrapping of wire around control tubes, thus "freezing" the controls. This threat is eliminated by the use of internal mast controls.

Internal mast control systems can be classified as either active or passive. Examples of these two types are shown in Figures 32 and 33. The active control system (Figure 32) eliminates the need for a mechanical swashplate since the control actuators are in the rotating system. However, it does require a slip ring for signal transmission and this requires a significant power supply since the actuators must function through each rotor cycle. The passive control system (Figure 33) operates on the same principles as a standard system, i.e., with a swashplate and mechanical linkages. This involves more complexity than the active system, but the power requirement is much less.

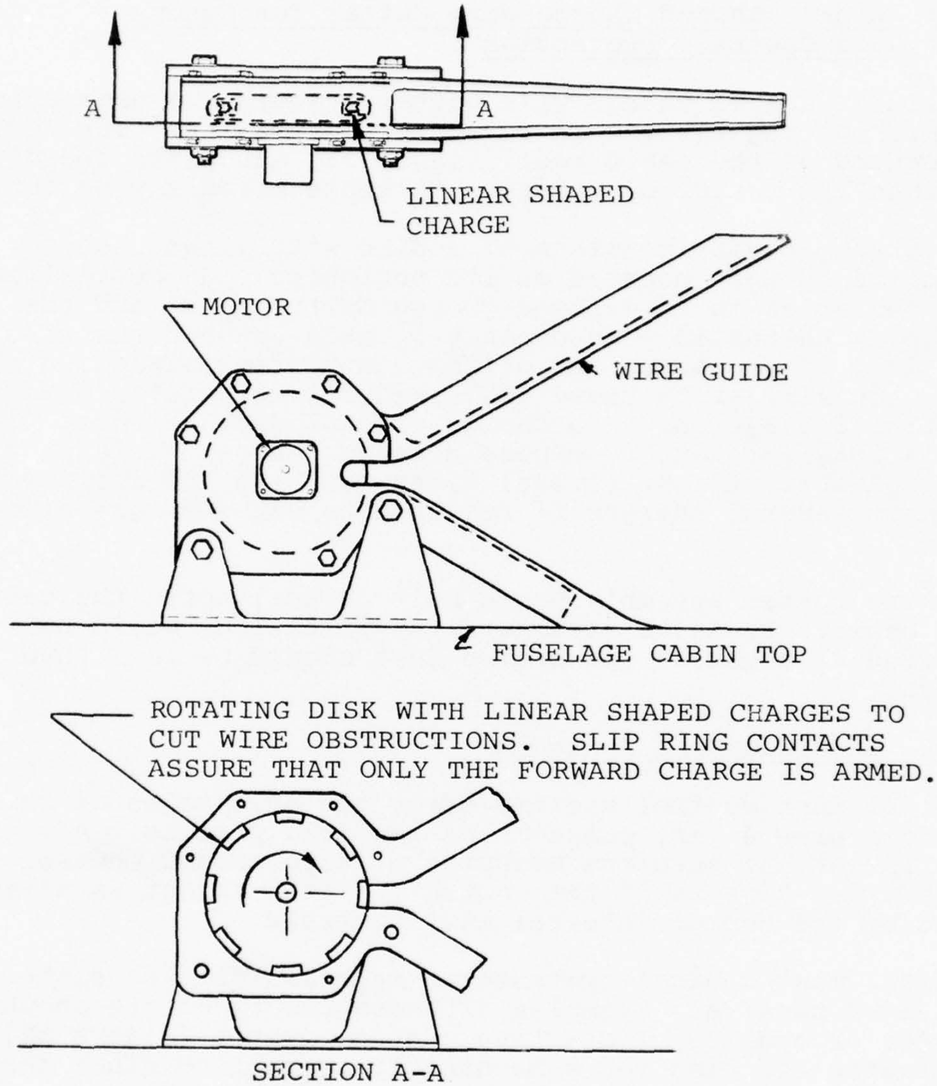

Figure 30. Linear Shaped Charge Wire Cutter for Canopy and Controls Protection

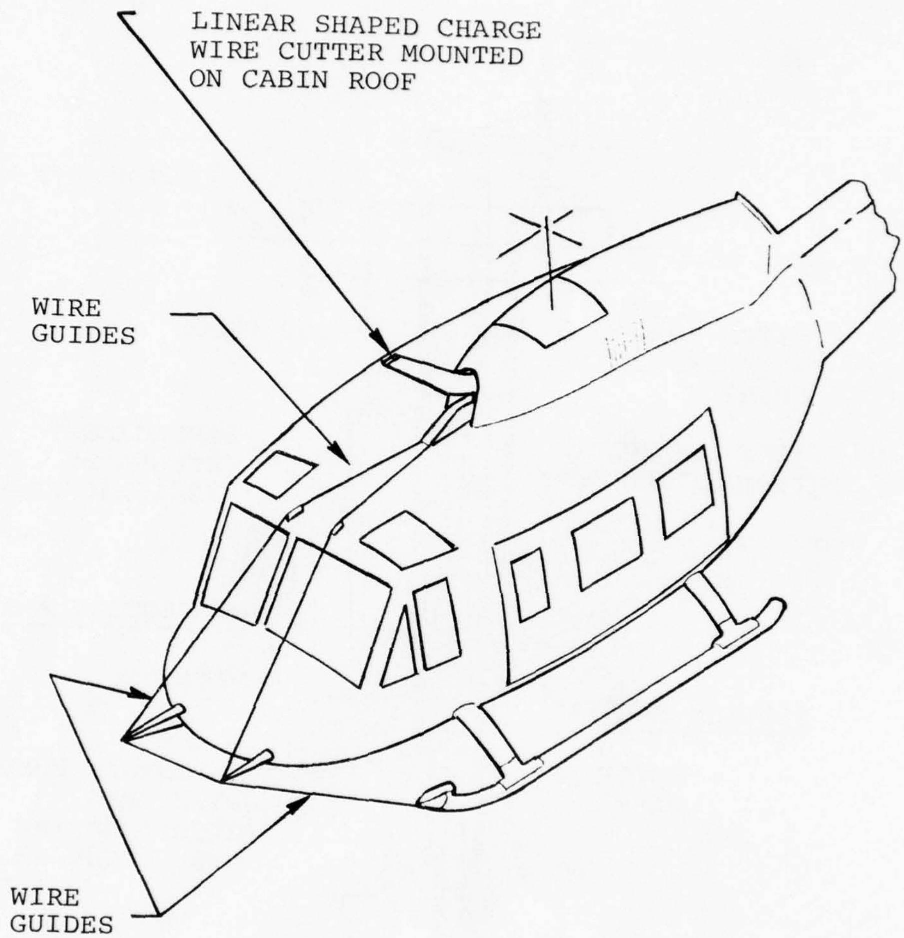

Figure 31. Linear Shaped Charge Wire Cutter

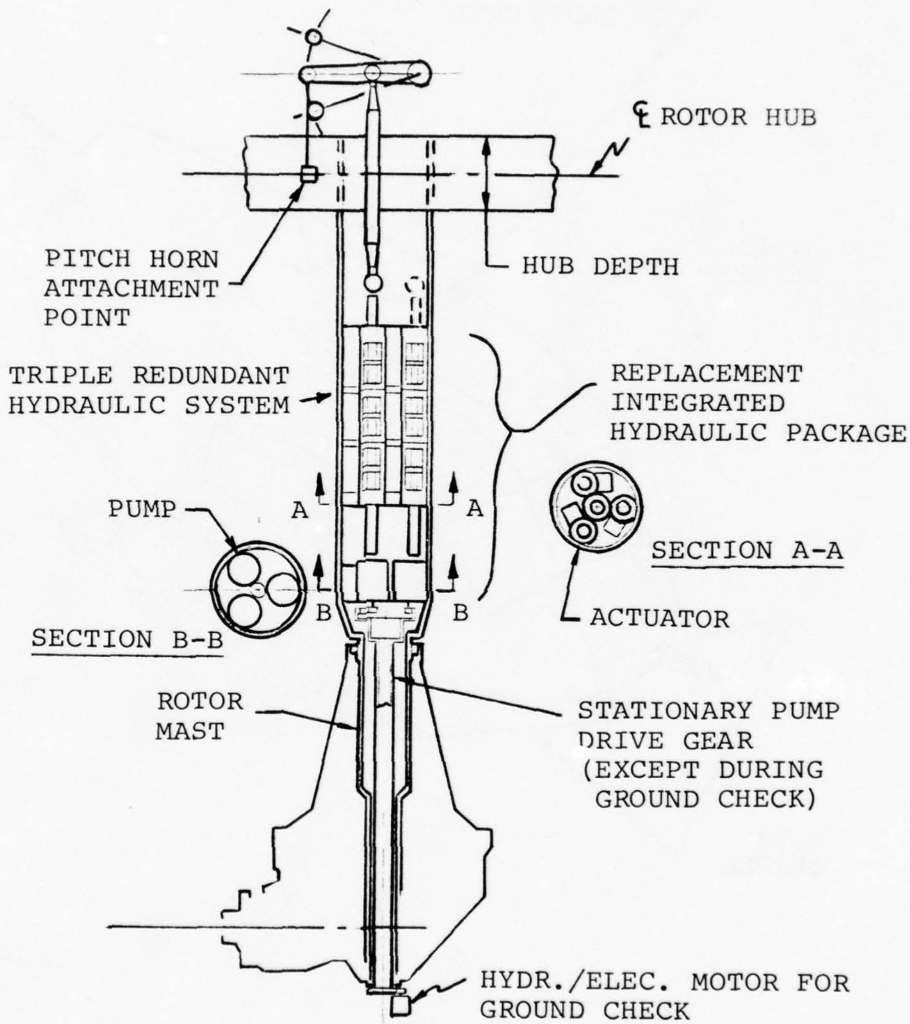

Figure 32. Active Actuator; Internal Mast Controls

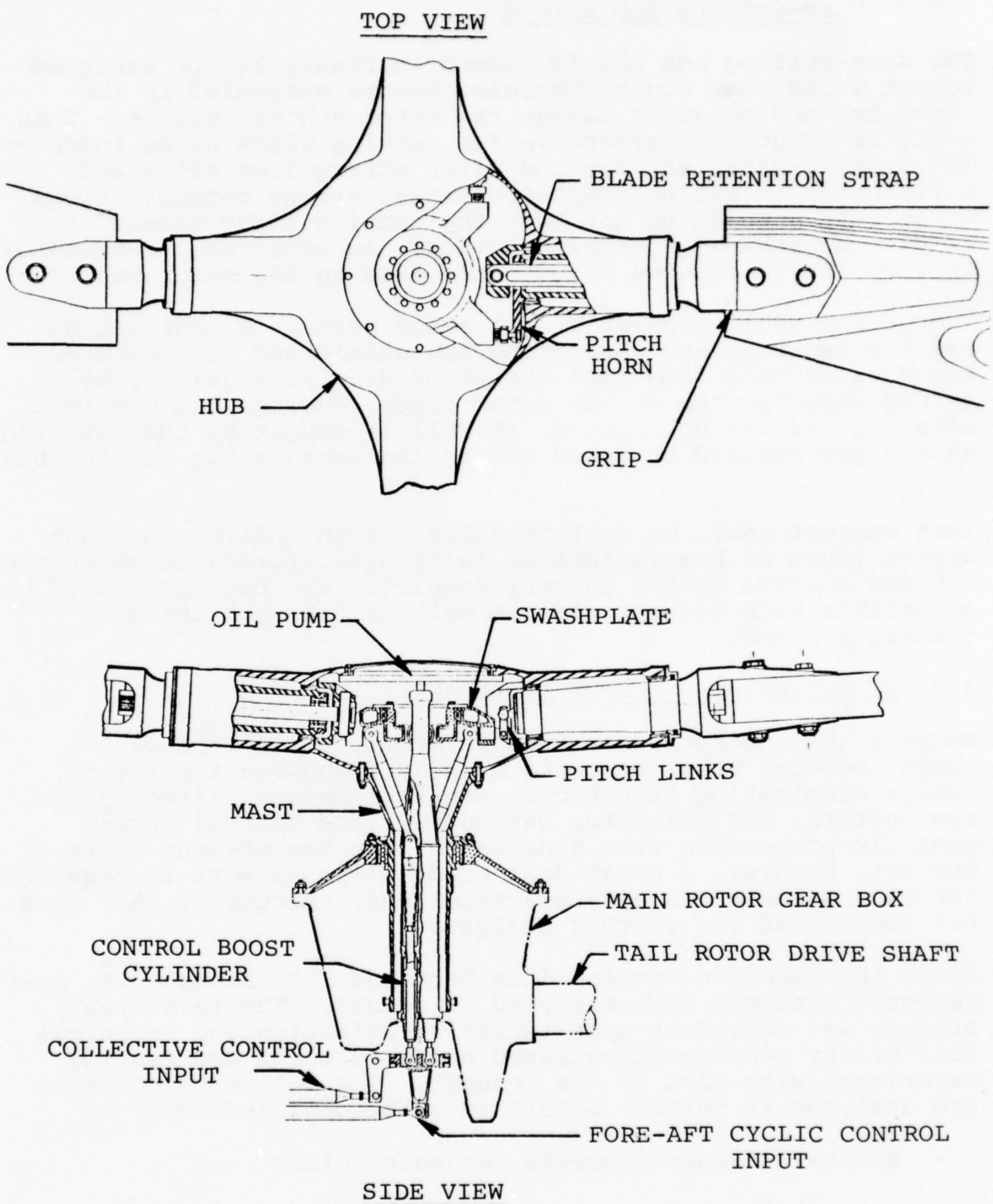

Figure 33. Internal Mast Controls (Mechanical)

3.6.3 Wire-Cutting Hub Shield

The wire-cutting hub shield, shown in Figure 34, is designed to cut wires that would otherwise become entangled in the rotor hub and possibly damage the rotor control system. This would be especially effective for cutting slack wires (such as TOW missile wire, strings and wires strung from kites and balloons as an antihelicopter defense, strung communications wires, etc.) which do not have the tension force needed to trigger a mechanical sensing device. An additional feature of this device is reduced aerodynamic drag on the rotor hub.

The device would consist of two basic parts: a nonrotating saw-toothed ring and a rotating hub shield and wire catcher. Slack wires that come into the rotor disc will quickly be guided into the hub by the rotor blade leading edge. When a wire reaches the hub shield, it will be caught by the rotating shield and sheared or sawed off by the nonrotating saw-toothed ring.

This concept would be most feasible for an entirely new hub design (such as bearingless or fully articulated) in which the hub and control system is very compact. The concept should be compatible with conventional as well as "through the mast" control systems.

3.7 SELECTION OF CONCEPTS TO BE ANALYZED

Besides the concepts described in Sections 3.3 through 3.6 above, several other concepts such as frangible tip rotors, energy dissipating structures, fan-in-fuselage, fixed system saw cutters, hub deflector bar cutter, and helical cutter controls protection were considered. In the present state of the art, however, a great deal of development work is required for making these concepts practical and, therefore, they were not considered for further analysis.

Among the concepts developed in Sections 3.3 through 3.6, only selected concepts were analyzed in detail. The selection process was dependent upon intuitive selection and technical feasibility consideration based on fabrication and testing experience with part of the concept. The following concepts are analyzed in further detail in subsequent sections:

- Strike-tolerant concepts for main rotors

    - strike-tolerant main rotor tips
    - high inertia and sharp leading-edge rotor
    - hingeless-bearingless rotor
    - pyrotechnic cutters on blade leading edges

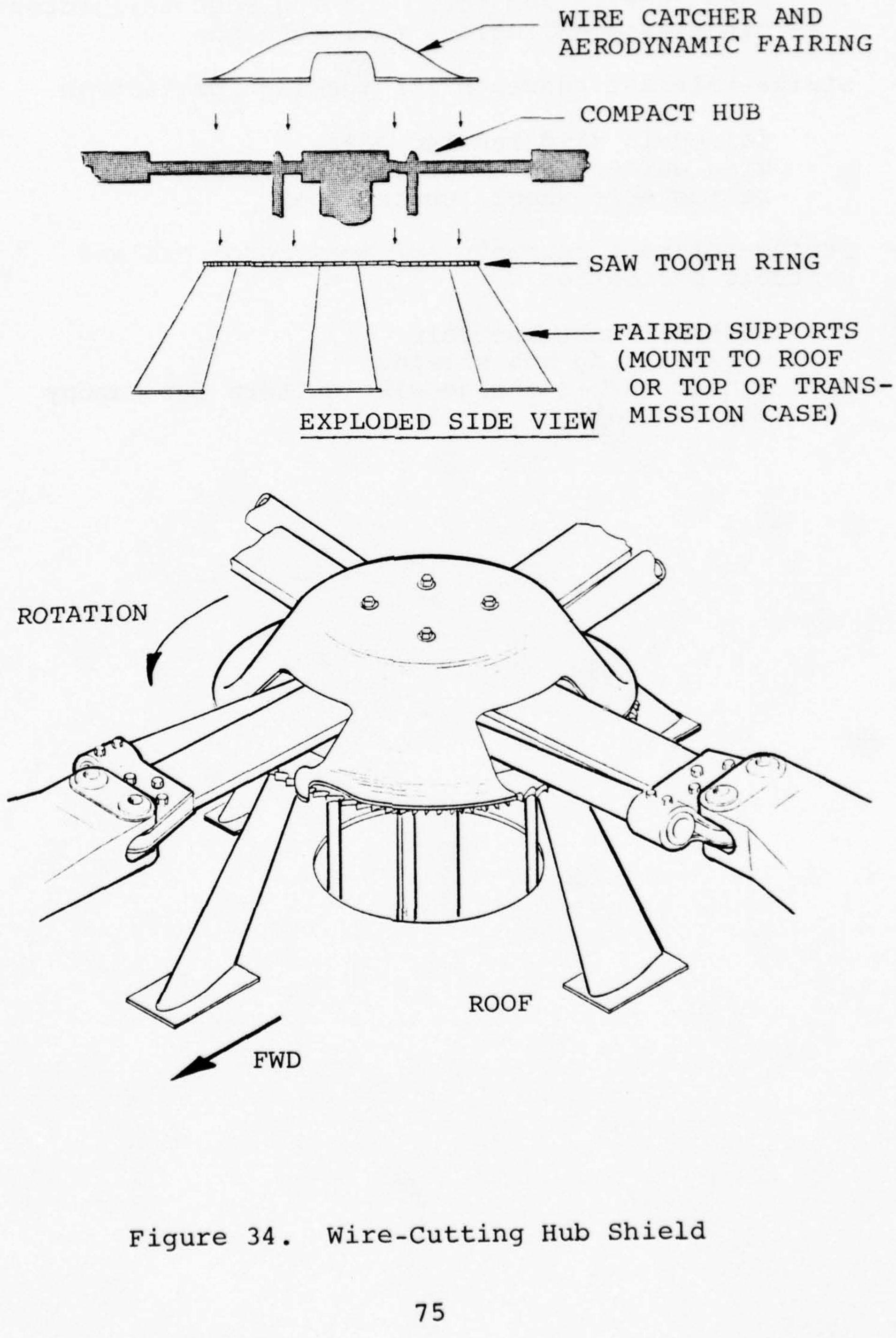

Figure 34. Wire-Cutting Hub Shield

- Strike-tolerant concepts for tail rotors

    - fan-in-fin
    - tail rotor shroud
    - strike-tolerant tail rotor tip
    - high inertia and sharp leading edge tail rotor
    - hingeless-bearingless tail rotors

- Strike-tolerant concepts for fuselage protection

    - faired-in skid landing gear
    - wire guides and knife-edge cutters
    - retractable wheel landing gear

- Strike-tolerant concepts for main rotor hub and controls protection

    - internal mast controls
    - wire-cutting hub shields
    - linear shaped charge wire cutters for canopy and controls

4. CONCEPT ANALYSES

4.1 BASELINE HELICOPTER

For sake of uniformity, the concepts were analyzed as implemented on a baseline helicopter. The present Army utility helicopter (Bell-manufactured Model UH-1D/H) is selected as the baseline helicopter for several reasons:

- The Model UH-1D/H constitutes 52 percent of the Army helicopter fleet.
- Extensive strike mishap data for peacetime and hostile environments are available for UH-1 series helicopters.

The baseline helicopter is only considered for the purpose of analyzing the relative merits of the design concepts. However, to establish a higher confidence level, the obstacle strike protection effectiveness was also evaluated for Models OH-58 and AH-1.

4.2 ANALYSIS CONSIDERATIONS

The concepts developed in Section 3 were analyzed for the following:

- Relative strike protection effectiveness
- Technical feasibility
- Baseline helicopter performance
- Helicopter retrofit suitability
- Initial installed cost
- Maintenance requirements
- Weight

The detailed analysis procedures, calculations, and significant findings for each of the analysis items is discussed subsequently.

4.3 RELATIVE STRIKE PROTECTION EFFECTIVENESS

This discussion applies to relative effectiveness comparisons. Absolute system effectiveness percentages are considered in Section 7.1.

The relative effectiveness implies a rating rather than a percentage. For the purpose of assigning a rating only, the concepts in a given area were compared to each other, i.e., one main rotor strike-tolerant concept was compared to another main rotor concept. In addition, the relative effectiveness was evaluated separately for tree and wire strikes. This was necessitated by the fact that the physical phenomena in wire and tree strikes are different.

The rating was divided into three broad categories - poor, average, and good. Rating in the ranges 1 through 3 is given if the effectiveness is considered to be poor. The rating is 4 through 7 for average effectiveness, and 8 through 10 for good effectiveness. The rating was subjectively assigned after reading the narratives for several accidents. The accident narratives often provide information related to strike locations, sequence of events in a strike situation, etc., which are helpful in assigning the ratings. Some of the examples are as follows:

- For Model OH-58 wire strikes, the antenna often cuts the communication wires.

- For main rotors, the tree strike damage is often limited to the outer 1-1/2 to 2 feet of the rotor blade.

The ratings for those obstacle strike-tolerant concepts analyzed are listed in Section 6.

4.4 TECHNICAL FEASIBILITY

Again, a rating scheme similar to the one used for evaluating the relative strike protection effectiveness was used. The technical feasibility analysis attempts to quantify the technical risks associated with implementing a given concept. Those concepts that are in the testing phase are more technically feasible than the ones which have only been considered in concept form.

4.5 WEIGHT

Some of the weights have already been mentioned in Section 3. For purposes of estimating the weights, standard aircraft weight estimation procedures have been used. The baseline helicopter weight distribution for major groups and subgroups is shown in Table 7. These data are for BHT Model 205 (Army designation UH-1H), Ship Number 13888.

The weight increments for obstacle strike protection devices are shown in Table 8. Two sets of incremental weights are provided, which correspond to weights for new designs and for

TABLE 7. BASELINE HELICOPTER WEIGHT DISTRIBUTION, MODEL UH-1H, SHIP NO. 13888

Component	Weight, lb	
M/R blade assembly	407.4	
M/R hub assembly	335.6	
Main Rotor Group		743.0
T/R blades	13.5	
T/R hub	17.0	
Tail Rotor Group		30.5
Fuselage - basic structure	529.3	
Boom - basic structure	114.3	
Secondary structure - fuselage	159.0	
Doors panels and misc - total	261.5	
Body Group		1064.1
Lighting Gear Group		120.9
Flight Controls Group		357.4
Engine Section Group		114.3
Propulsion Group		1603.8

TABLE 8. INCREMENTAL WEIGHTS FOR OBSTACLE STRIKE PROTECTION DEVICES

	Δ Weights, lb	
Concepts	New	Retrofit
Main Rotor		
1. Strike-tolerant M/R tip	0	0
2. High-inertia and sharp L.E. rotor	+150	>150
3. Hingeless-bearingless rotor	-74	
4. Pyrotechnic cutters on L.E.	+45	+67.5
Tail Rotor		
5. Fan-in-fin	0	>0
6. Tail rotor shroud	+4	+4
7. Strike-tolerant T/R tip	+2	+2
8. High-inertia and sharp L.E. T/R	+10	>10
9. Hingeless-bearingless T/R	-5.6	
Fuselage System		
10. Faired-in skid landing gear	+32	+32
11. Wire guides and knife-edge cutters	+35	+35
12. Retractable wheel landing gear	+330	
Main Rotor Hub and Controls		
13. Internal mast controls		
(mechanical)	+150	
(electrical)	0	
14. Wire-cutting hub shield	+35	+35
15. LSC wire cutters for canopy controls	+22	+22

retrofit designs. The blank columns indicate a situation where a reasonable estimate could not be made or was not applicable.

4.6 BASELINE HELICOPTER PERFORMANCE

The obstacle strike protection devices, when incorporated on a helicopter, will influence baseline helicopter performance. In most cases, a degradation in performance will occur, but some obstacle strike protection can be designed to maintain or improve the performance. The effect of incorporating the devices on a baseline helicopter is evaluated in terms of frontal drag area increase, incremental weight change (as specified in the previous section), and in terms of increased horsepower required to perform a given mission.

The main and tail rotor obstacle strike tolerance concepts, with the exception of the fan-in-fin, can be designed to have no adverse effects on helicopter performance; in fact, the incorporation of a hingeless-bearingless main rotor would reduce power required to hover by 0.83 percent due to the hub weight reduction of about 74 pounds.

The fuselage protection devices influence the baseline helicopter performance by increasing the fuselage parasite drag area and the empty weight of the aircraft. Of the concepts being considered, the faired-in skid landing gear and wire guides with knife-edge cutters add a parasite drag area of approximately 0.15 feet^2 and an empty weight increase of 67 pounds, which increases the horsepower required at hover by 0.83 percent and at 100 knots forward airspeed by about 0.67 percent. A wheeled landing gear in flight adds about 330 pounds of empty weight and 3.6 feet of parasite drag area in forward flight. This has the effect of increasing horsepower required to hover by 4.01 percent and, if the helicopter is flown at 100 knots with the wheels extended, the horsepower required will increase over the baseline condition by 10.02 percent.

For the main rotor hub and controls protection devices, the performance penalties are as follows. The linear-shaped charge wire cutter for canopy and controls protection will add about 22 pounds and 0.83 feet^2 of parasite drag area causing an increased horsepower requirement of 0.35 percent at hover and 2 percent at 100 knots. The wire cutting hub shield adds 35 pounds and can be shaped to have very low drag. With proper shape, it is possible to decrease the parasite drag area by 0.36 feet^2. These weight and drag changes have the effect of increasing the power required to hover by 0.47 percent and decreasing power required at 100 knots by 0.67 percent. Internal mast controls will require the mast diameter to be greater than that of conventional masts. This type of mast and control system arrangement would increase the empty weight by approxi-

mately 150 pounds and the parasite drag area by 0.20 feet^2. The required power increases would be 1.89 percent at hover and 1.34 percent at 100 knots.

Based on the changes expected in weight, parasite drag area, and horsepower requirements as described above, the concepts are again assigned a rating on a scale of 1 to 10 to reflect the effect on baseline helicopter performance.

4.7 HELICOPTER RETROFIT SUITABILITY

For the purpose of retrofit suitability evaluation, the helicopter obstacle strike protection devices could be categorized into three broad categories as follows. A protection device had good retrofit suitability if it could be retrofitted on an existing component. Retrofit suitability, however, was average if a protection device could be retrofitted by replacing a component. On the other hand, retrofit suitability was poor if the protection device could not be retrofitted or if retrofitting necessitated extensive helicopter changes. The retrofit suitability was quantified in terms of a rating scheme similar to that discussed in Section 4.3.

To illustrate by an example, a faired-in skid landing gear can be implemented on the helicopter by adding structural elements to the existing landing gear, which means that the retrofit suitability is good. An example of an average retrofit suitability is the high inertia and sharp leading-edge rotor. To implement this protection device, a whole new rotor system (including controls) has to be implemented. Examples of poor retrofit suitability items are retractable wheel landing gear and the internal mast controls.

The ratings tabulated in Section 6 are the averages of several subjective evaluations made based on the above guidelines.

4.8 INITIAL INSTALLED COST

Initial installed cost for an obstacle strike protection device has been defined to be the cost incurred to the point of releasing the production drawings. Specifically, initial installed cost includes the costs associated with design and design support testing, functional and fatigue testing, and flight testing to prove the concept.

The initial installed cost ratings were arrived at in the following manner. First, the initial installed cost was estimated in man-hour units. Within each of the helicopter areas (e.g., main rotor, tail rotor, etc.) the concepts were normalized to each other. In the given area, the maximum cost item was selected. The initial installed cost of all the

strike protection concepts in that area was divided by the maximum cost to give a cost ratio. The inverse of the ratio was used as the rating to reflect the initial installed cost. The same process was used for all helicopter areas.

4.9 MAINTENANCE REQUIREMENTS

For maintenance evaluation, the following requirements were considered on a comparative basis:

- System installation and operational requirements
- System preventive and corrective maintenance requirements
- System spare parts requirements
- System tool and ground support equipment requirements
- System maintenance and operational personnel requirements

The comparative basis evaluation was quantified in terms of a rating system similar to that used for evaluating technical feasibility, retrofit suitability, etc.

Particular attention was paid to the strike protection concepts using explosive devices, namely pyrotechnic cutters on leading edges and linear shaped charge wire cutters for canopy and controls. The presence of detonators and detonator circuits in these concepts will increase the requirement for more fully trained personnel in the field to inspect and check detonation functions to assure safety and operational capability.

The wire guides and knife-edge cutters concept is acceptable in terms of maintainability. No added technical training for maintenance personnel will be required for the average helicopter. Some covers will probably be required for the wires and cutters when the helicopter is on the ground to prevent ground personnel from being injured by the sharp cutting surfaces.

Incorporation of a retractable wheel landing gear necessitates an increase in hydraulics, actuators, additional linkage mechanisms, and a brake system. These additions make the retractable wheel landing gear least desirable from the maintainability point of view.

5. OBSTACLE AVOIDANCE TECHNIQUES

5.1 HUMAN PERCEPTION OF OBSTACLES

The direct sensing of wires and other obstacles that provide a hazard to flight is achieved by the human eye. Visual perception of these objects is subject to many complex qualities of human vision. The ability of the eye to see an object is dependent upon the angle that object subtends on the retina, or visual acuity. A general rule for visual acuity states that the eye of the average viewer can detect a gap of about 1 minute of visual angle at ordinary indoor light levels. This rule is designed for people with normal eyesight and for targets that have high brightness contrasts. As these factors are degraded, the size of the angle subtended upon the retina must increase. This rule relates to the cross section of the pattern observed. It does not strictly hold for wires, where the data available in the literature are not complete.

If there is a round object which is 1/2 inch in diameter, using the "1-minute rule," it could first be detected 143 feet away. If the person viewing the object is in a helicopter traveling at 60 mph, or 88 feet per second, the object will be overtaken in less than 2 seconds.

The time to view either outside the aircraft or a display will vary with many things, particularly the pilot workload. For purposes of discussion, considering all things optimum and looking at the time required to view an object, the response times involved are shown below.

	Approximate Time, sec
Pilot detects object and his eyes move to object and focus on it	0.3
Pilot sees object clearly and interprets the image	0.6
Pilot selects course of action	0.5
Pilot response time	0.3
Viewing Time for One Object	1.7

If the aircraft is flying 60 mph, then in the time that it takes for the pilot to see something and decide on a course of action he has traveled 149.6 feet. This does not consider the response

time of the vehicle itself to move in space once the control motion has been made. This may vary as much as several seconds depending upon the vehicle, the speed, the dynamic response characteristics, etc. With this example, it can be seen that under optimum conditions, with a vehicle traveling only 60 mph, the human eye cannot be relied on to be the sensor of objects of this magnitude. (Obstructions to vision in the form of rain, snow, fog, and night will provide additional lags to the visual process if they do not obliterate objects entirely.)

5.2 OBSTACLE DETECTION CONCEPTS AND DEVICES

The analysis of obstacle strike mishaps indicates that in a high proportion of cases the obstacle was not seen. This is particularly true of wires. Occasionally, the strung wires are totally or partially obscured, while at other times they blend into the background. In night-time low-level flight, wire strikes are, of course, serious threats.

The following are important detection methods.

- Precise navigation and obstacle maps
- Visual
- TV or infrared
- Radar, using microwaves or laser

Two important developments for helicopter applications are discussed in References 7 and 8.

- Gated Low Light Level TV (GL^3TV)
- Laser Obstacle Terrain Avoidance Warning System (LOTAWS)

The objective of these devices is to improve the practical and tactical utilization of helicopters for low-level day/night operations by providing a means of detecting wire obstacles. The desirable requirements for the detection system are to detect wires whose diameters are 1/8 inch or more and which are located up to 1000 feet away from the aircraft. Some of the pertinent details of the two promising systems mentioned above are described subsequently.

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[7]Kleider, A., AN EXPERIMENTAL EVALUATION OF A GATED LOW LIGHT LEVEL TV FOR WIRE DETECTION, ECOM Technical Report 4321, U. S. Army Electronics Command, Fort Monmouth, New Jersey, May 1975, AD A010331.

[8]Kleider, A., A LOW COST OBSTACLE WARNING SYSTEM, U. S. Army Avionics Laboratory, U. S. Army Electronics Command, Fort Monmouth, New Jersey, 1973, AD 785644.

5.2.1 Gated Low Light Level TV (GL^3TV)

Reference 7 is briefly discussed in the following paragraphs.

In the GL^3TV system, the scene is imaged by the external optics on the fiber-optic faceplate of an image intensifier. The rear face of the input fiber-optic is a photoemissive surface. Photoelectrons are emitted by a photocathode and accelerated by an externally applied electric field. The accelerated photoelectrons gain kinetic energy in their transit across the field and impinge upon a phosphor secondary imaging surface. Multiple photoelectrons are emitted by the phosphor and thus the amplified image is transmitted by an output fiber-optic faceplate to the input of an EBS isocon. A similar photoemissive process in the isocon causes the impingement of photoemissive electrons on the silicon diode matrix target. The target surface is read with a scanning beam of electrons and the output video information is processed to yield the display image.

The feasibility of a GL^3TV system, in clear weather as well as in dark conditions up to and including dawn, has been demonstrated. The investigation reported in Reference 7 points out three areas requiring some intensive investigation before a complete system specification can be developed. The first area deals with the effectiveness of the system in overcast, haze, and moderate fog conditions. The second area requires extensive work with human factors interface. The man/display/decision interface should be replaced at a later date with automatic pattern recognition processing of the video information. The third and most important task is concerned with overcoming the limitations of a very small field of illumination and reception.

5.2.2 Laser Obstacle Terrain Avoidance Warning System (LOTAWS)

The LOTAWS system employs a carbon dioxide 10.6-micron heterodyning radar technique for detection of obstacles. The description of LOTAWS given here is based on a summary of the work reported in Reference 9.

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[9] THE DEVELOPMENT AND TESTING OF A LASER OBSTACLE TERRAIN AVOIDANCE WARNING SYSTEM (L)TAWS), UTRC 76-99, Presented at the 7th DoD Conference on Laser Technology, June 1976. (Work supported under ECOM Contract DAAB07-72-C-0145.)

The heterodyning laser radar used in the LOTAWS system was developed by the United Technologies Research Center (UTRC) and has been tested in a CH-53 helicopter. The system demonstrated detection of off-axis 1/8-inch field wire at typical ranges of 1500 feet, and the vibrational environment of the helicopter did not seriously degrade the system's performance.

The technical approach to LOTAWS is based on the considerations of weather penetration, incoherent and coherent optical detection capabilities, Doppler shifts caused by target and aircraft velocity uncertainties, and the achievable state of the art in lasers and heterodyne detection.

Operationally, a 250 micro-rad beam is directed via a germanium duplexer to anywhere in a 30-degree conical field by an electronically programmable wedge scanner. Typical scan patterns are linear, spiral, or circular. The return radiation is mixed for heterodyning with a continuous wave oscillator at the duplexer. A signal processor then determines range and discriminates between wire targets and background images.

The pilot's display is a video screen showing the LOTAWS signal superimposed on a video image of the background terrain from a nose-mounted TV camera.

6. SELECTION OF CONCEPTS

6.1 CONCEPT SELECTION PROCEDURES

Acceptance of an obstacle strike protection concept is dependent upon its expected functional and operational performance. The expected performance of a given concept has been evaluated in Section 4 in the important functional and operational areas of strike protection effectiveness, technical feasibility, effect on baseline helicopter performance, helicopter retrofit suitability, initial installed cost, maintenance requirements, and minimum weight impact. In order to arrive at a composite acceptance rating, weighting factors were assigned to each of these analysis areas. The weighting factors for all the analysis factors were assumed equal except for the factor of strike protection effectiveness. The strike protection effectiveness was assigned a weighting factor of 2, compared to a weighting factor of 1 for the remaining analyses factors. Maximum scores which account for the weighting factors appear on the last row of the comparative analyses tables.

Since helicopters have been divided into four major areas for the purpose of designing obstacle strike protection devices, separate comparative analyses tables have been prepared for each of these areas. Furthermore, separate tables are prepared for wire strike and tree strike protection.

For the purpose of illustration, consider Table 9. This is the comparative analysis table for wire strike protection and the main rotor concepts are being compared. The numbers in the body of the matrix are the ratings arrived at during the analysis of Section 4. The number in the total score column reflects the sums of the individual ratings multiplied by the weighting factors. The total score reflects a composite rating indicating the degree to which that concept will meet the design goal of eliminating or minimizing the strike hazard. The maximum possible total score is 80.

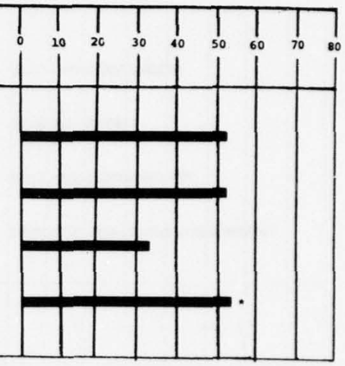
The total score can be used for selecting the most promising concept. Where the concepts are mutually exclusive, the concepts with the highest total score should be selected. However, if the concepts are not mutually exclusive (for example, in the fuselage area or in the hub and controls area), more than one concept can be selected if the total scores are high.

6.2 SELECTED CONCEPTS

The comparative analysis of the concepts is shown in Tables 9 through 16. Separate tables have been prepared for each major area of the helicopter requiring strike protection. In addition, the threat of wire and tree strikes has been considered separately.

TABLE 9. COMPARATIVE ANALYSIS FOR MAIN ROTOR PROTECTION AGAINST WIRE STRIKES

PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
STRIKE-TOLERANT M/R TIP	2	8.8	9	7.1	8.6	8	9	52.6	2
HI-INERTIA & SHARP L.E. ROTOR	14	7.8	9	5.4	8.8	3	4	52.0	3
HINGELESS-BEARINGLESS ROTOR	3	6.6	9	4.0	1.0	4	6	33.6	4
PYROTECHNIC CUTTERS ON L.E.	18	7.6	9	6.0	5.6	6	1	53.2	1
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	

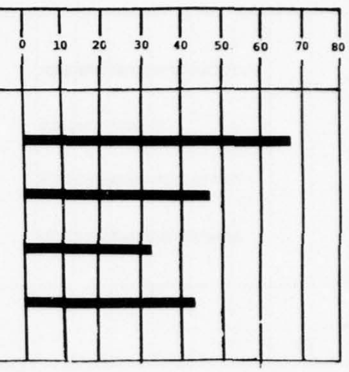


LEADING EDGE PYROTECHNIC CUTTERS ALTHOUGH ARE UNDESIRABLE FROM SEVERAL POINTS OF VIEW, ARE EXPECTED TO BE VERY EFFECTIVE AGAINST WIRES.

NOTES:
1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.
3. * means selected concept.

TABLE 10. COMPARATIVE ANALYSIS FOR MAIN ROTOR PROTECTION AGAINST TREE STRIKES

PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
STRIKE-TOLERANT M/R TIP	17	8.8	9	7.2	8.6	8	9	67.6	1
HI-INERTIA & SHARP L.E. ROTOR	9	7.8	9	5.4	8.8	3	4	47.0	2
HINGELESS-BEARINGLESS ROTOR	2	6.6	9	4.0	1.0	4	6	32.6	4
PYROTECHNIC CUTTERS ON L.E.	8	7.6	9	6.0	5.6	6	1	43.2	3
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	

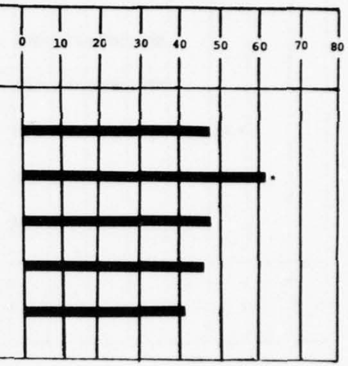


STRIKE-TOLERANT TIPS IS EXPECTED TO BE MOST EFFECTIVE AGAINST TREE STRIKES

NOTES:
1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.

TABLE 11. COMPARATIVE ANALYSIS FOR TAIL ROTOR PROTECTION AGAINST WIRE STRIKES

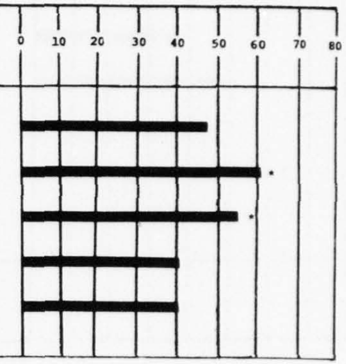
PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
FAN-IN-FIN	17	8.2	7	4.2	1.0	3	7	47.4	2
TAIL ROTOR SHROUD	16	8.2	9	7.2	5.3	6	10	61.7	1
STRIKE-TOLERANT T/R TIP	4	8.2	9	7.8	5.3	7	3	47.3	4
HI-INERTIA & SHARP L.E. T/R	12	7.2	9	5.8	2.4	5	4	45.6	3
HINGELESS-BEARINGLESS T/R	3	8.2	9	6.4	1.5	7	6	41.1	5
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	



NOTES: 1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.
3. * means selected concept

TABLE 12. COMPARATIVE ANALYSIS FOR TAIL ROTOR PROTECTION AGAINST TREE STRIKES

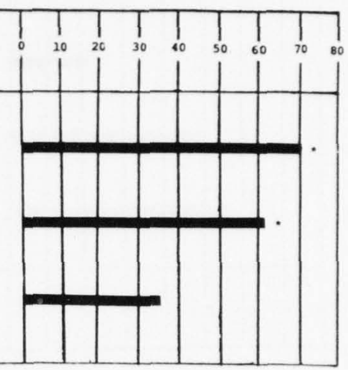
PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
FAN-IN-FIN	17	8.2	7	4.2	1.0	3	7	47.4	3
TAIL ROTOR SHROUD	15	8.2	9	7.2	5.3	6	10	60.7	1
STRIKE-TOLERANT T/R TIP	15	8.2	9	7.8	5.3	7	3	55.3	2
HI-INERTIA & SHARP L.E. T/R	7	7.2	9	5.8	2.4	5	4	40.4	4
HINGELESS-BEARINGLESS T/R	2	8.2	9	6.4	1.5	7	6	40.1	5
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	



NOTES: 1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.
3. * means selected concept.

TABLE 13. COMPARATIVE ANALYSIS FOR FUSELAGE SYSTEM PRTOECTION AGAINST WIRE STRIKES

PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
FAIRED-IN-SKID LANDING GEAR	17	9.2	8	8.8	10	7	10	70	1
WIRE GUIDES KNIFE-EDGE CUTTERS	16	8.8	8	8.8	7.9	6	6	61.5	2
RETRACTABLE WHEEL LANDING GEAR	18	6.4	3	3.2	1.0	1	3	35.6	3
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	

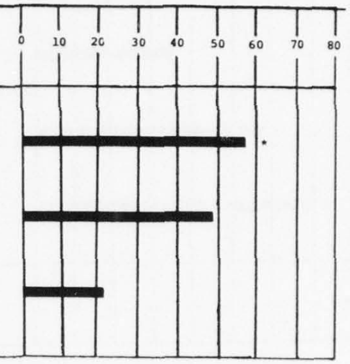


FAIRED-IN-SKID LANDING GEAR AND WIRE GUIDES KNIFE-EDGE CUTTERS ARE NOT MUTUALLY EXCLUSIVE, SO BOTH HAVE BEEN SELECTED

NOTES: 1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.
3. * means selected concept.

TABLE 14. COMPARATIVE ANALYSIS FOR FUSELAGE SYSTEM PROTECTION AGAINST TREE STRIKES

PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
FAIRED-IN-SKID LANDING GEAR	4	9.2	8	8.8	10.0	7	10	57*	
WIRE GUIDES KNIFE-EDGE CUTTER	3	8.8	8	8.8	7.9	6	6	48.5	
RETRACTABLE WHEEL LANDING GEAR	4	6.4	3	3.2	1.0	1	3	21.6	
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	

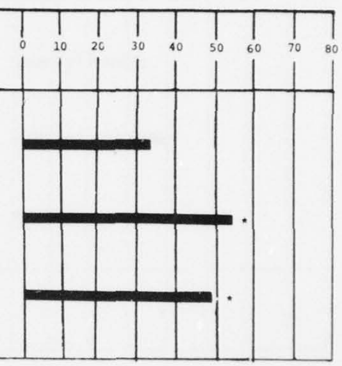


NONE OF THE CONCEPTS EFFECTIVE AGAINST TREE STRIKES. FAIRED-IN-SKID LANDING GEAR ELIMINATES SOME SNAGGING, HENCE SELECTED

NOTES:
1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.
3. * means selected concept.

TABLE 15. COMPARATIVE ANALYSIS FOR HUB AND CONTROLS PROTECTION AGAINST WIRE STRIKES

PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAI TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
INTERNAL MAST CONTROLS	14	5.2	6	3	1.0	1	3	33.2	3
WIRE-CUTTING HUB SHIELDS	15	6.6	9	4.6	2.8	6	10	54	1
LSC WIRE CUTTERS FOR CANOPY AND CONTROLS	16	7.2	7	6.0	4.3	7	1	48.5	2
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	



HUB SHIELDS ARE FOR SLACK WIRES, LSC WIRE CUTTERS ARE FOR POWER AND COMM. LINES, BOTH CONCEPTS SELECTED

NOTES:
1. Numbers in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.
3. * means selected concept.

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HELICOPTER OBSTACLE STRIKE TOLERANCE CONCEPTS ANALYSIS.(U)
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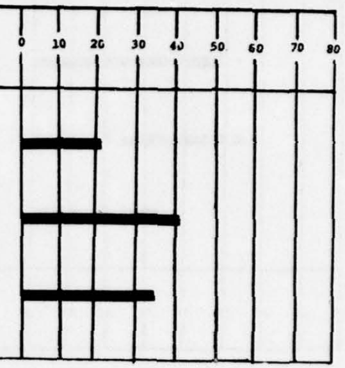
TABLE 16. COMPARATIVE ANALYSIS FOR HUB AND CONTROLS PROTECTION AGAINST TREE STRIKES

PROMISING CONCEPT	MAXIMUM EFFECTIVENESS	MAXIMUM TECHNICAL TECHNICAL FEASIBILITY	MINIMUM LOSS OF PERFORMANCE	MAXIMUM RETROFIT SUITABILITY	MINIMUM INITIAL INSTALLED COST	MINIMUM WEIGHT PENALTY	MINIMUM MAINTENANCE REQUIREMENTS	TOTAL SCORE	COMPARATIVE RATING
INTERNAL MAST CONTROLS	2	5.2	6	3	1.0	1	3	21.2	3
WIRE-CUTTING HUB SHIELDS	2	6.6	9	4.6	2.8	6	10	41.0	1
LSC WIRE CUTTERS FOR CANOPY AND CONTROLS	2	7.2	7	6.0	4.3	7	1	34.5	2
MAXIMUM SCORE POINTS	20	10	10	10	10	10	10	80	



NONE OF THE CONCEPTS EFFECTIVE AGAINST TREE STRIKES, NONE SELECTED.

NOTES:
1. Number in body of matrix represent degree of merit expressed in percent.
2. Number in total score column is sums of the individual ratings and the maximum score points.

For protecting the main rotor against wire strikes, the concept of pyrotechnic cutters on the rotor blade leading edge was found to be most promising. As shown in Table 9, this concept was undesirable from the maintenance and cost point of view, but becomes attractive due to its high effectiveness in protecting the rotor against wire strikes.

When main rotor protection against tree strikes is considered, as shown in Table 10, the strike-tolerant main rotor tip becomes more attractive than the blade leading-edge pyrotechnic cutters. The strike-tolerant main rotor tip, when properly designed, is expected to be very effective in protecting against tree strikes. Additional advantages are low initial cost and low maintenance requirements.

The tail rotor concepts for wire strike protection are shown in Table 11. Comparative analysis indicates the tail rotor shroud to be most promising. Besides having the potential of being very effective aginst wire strikes, the technical feasibility of the tail rotor shroud has been demonstrated in model tests. Initial installed cost of a shroud on the tail rotor also seems to be acceptable. The fan-in-fin is a technically proven concept, since it is a flight article in currently flying helicopters. The fan-in-fin system on a UH-1H helicopter on retrofit basis, however, is undesirable from the point of view of initial installed cost, weight penalty, and retrofit suitability. On a new helicopter design, the fan-in-fin would compare favorably to the shrouded tail rotor.

Concepts that will improve survivability of the tail rotor in tree strikes are compared in Table 12. The shroud is effective against tree strikes by deflecting the tree branches, while the strike-tolerant tail rotor tips would be crushed under a strike situation. On a retrofit basis, the selected concepts are the tail rotor shroud or a strike-tolerant tail rotor tip. For a new design, however, the fan-in-fin would be competitive with the tail rotor shroud and strike-tolerant tail rotor tips.

Comparisons are shown in Table 13 for fuselage system protection against wire strikes. In this case the concepts under consideration are not mutually exclusive. Wire guides and knife-edged cutters could be combined either with skid gear or wheel gear. Based on total scores, the faired-in skid landing gear, wire guides, and knife-edged cutters are selected. Retractable wheel landing gear is undesirable from a retrofit point of view; however, it enables safer landing at higher sink rates and therefore is desirable on new designs.

In tree strike situations, all concepts mentioned in Table 14 are ineffective in protecting the fuselage. Faired-in skid

landing gear might be helpful from the standpoint of eliminating some of the snagging.

The hub and controls protection concepts are compared in Tables 15 and 16. Since the concepts comparated are not mutually exclusive for wire strike protection, both the wire-cutting hub shield and LSC (linear shaped charge) wire cutters for canopy and controls are selected concepts. It should be pointed out that wire-cutting hub shields are effective against slack wires, while the LSC wire cutters are expected to be effective against power and communication lines.

6.3 SYSTEM EFFECTIVENESS CONSIDERATIONS

So far, the concepts for protecting a given helicopter area have been compared to each other for the purpose of estimating their relative effectiveness. The system effectiveness rate of a given concept is generally defined as the percentage of obstacle strike mishap reductions that might result from the introduction of that concept on the helicopter. Also, specific system effectiveness rate is defined for a specific obstacle and specific mishap class. For calculating system effectiveness rates, the percentage of strikes occurring in the area where the concept under consideration is being introduced should be known. The details of helicopter strike areas have been discussed in Section 2. Some of the results pertaining to the helicopter strike areas will be used in the section to evaluate the system effectiveness rates of the concepts which have been selected in previous sections.

The system effectiveness rates are shown in Tables 17 through 19 for helicopter Models UH-1, AH-1 and OH-58, respectively.

In Table 17, the system effectiveness rates for the promising obstacle strike concepts were calculated for Model UH-1. Different effectiveness rates have been calculated for different obstacles. The first set of three columns shows the calculations for all obstacle strikes and all mishap classes. For this case, relative effectiveness is calculated by weighing tree and wire strike effectiveness numbers. To illustrate through an example, the pyrotechnic blade leading-edge cutter has a relative effectiveness of 40 percent for tree strikes and 90 percent for wire strikes. During the period 1972 through November 1977 there were 233 tree strikes and 50 wire strikes for Model UH-1. The calculated relative effectiveness, therefore, is 48.8 percent = (233 x 40 + 50 x 90)/(233+50). The system effectiveness rate is obtained by multiplying the first column (percentage rate at which the helicopter area, where the concept is introduced, is being struck) times the second column (which corresponds to the relative effectiveness). For example, in Table 17 the pyrotechnic

TABLE 17. OBSTACLE STRIKE SYSTEM EFFECTIVENESS CONSIDERATION FOR MODEL UH-1

Selected Concept	All Obstacles and All Mishaps			Tree Strike Accidents			Wire Strike Accidents			Wire Strike Mishaps		
	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %
1. Pyrotechnic Cutters on LE	49.7	48.8	24.3	16.7	40.0	6.7	0.0	90.0	0.0	8.33	90.0	7.5
2. Strike-tolerant M/R Tip	49.7	71.7	35.6	16.7	85.0	14.2	0.0	10.0	0.0	8.33	10.0	0.8
3. Tail Rotor Shroud	7.6	75.9	5.8	I/D	75.0	-	42.9	80.0	34.0	12.5	80.0	10.0
4. Strike-tolerant T/R Tip	7.6	65.3	5.0	I/D	75.0	-	42.9	20.0	8.6	12.5	20.0	2.5
5. Faired-in Skid Landing Gear	1.7	31.5	0.5	I/D	20.0	-	0.0	85.0	0.0	16.7	85.0	14.2
6. Wire Guides & Knife-edge Cutters	10.4	26.5	2.8	I/D	15.0	-	14.3	80.0	11.4	20.8	80.0	16.7
7. Wire Cutting Hub Shields	3.9	21.5	0.8	I/D	10.0	-	14.3	75.0	10.7	16.7	75.0	12.5
8. LSC Wire Cutters for Canopy and Controls	3.9	22.4	0.9	I/D	10.0	-	14.3	80.0	11.4	16.7	80.0	13.4

NOTES: I/D Inadequate Data Base
N/A Not Analyzed
* Relative effectiveness is a composite number calculated by weighing tree and wire strike incident numbers (233:50).
Eff. means Effectiveness

cutters system effectiveness rate is 24.3 percent, which is the product of 49.7 and 48.8 percent. Thus, the introduction of pyrotechnic cutters on blade leading edges is expected to eliminate about 24 percent of all obstacle strikes in all mishap classes.

The three remaining sets of system effectiveness rate calculations have been performed for tree and wire strike accidents and for wire strike mishaps (accidents being mishap classes one through three).

For Model UH-1 obstacle strikes, the following overall conclusions can be made. The concepts developed for minimizing main and tail rotor damage are effective in reducing all obstacle strikes in all classes. Looking at only tree strike accidents, however, the system effectiveness rate of the main rotor concepts goes down. The data base for remaining helicopter areas is inadequate in the sense that there are several unknown factors in the accidents. For wire strike accidents, the system effectiveness rate distributions are different. Large gains can be made by protecting the tail rotor and helicopter fuselage and controls area. For wire strike accidents and mishaps, fuselage and controls area concepts become even more effective while the tail rotor concepts are relatively less effective.

Table 18 shows the system effectiveness rate calculations for Model AH-1. The overall conclusions are about the same as for the Model UH-1, except that for tree strike accidents the tail rctor area protection is expected to be very effective. For fuselage and controls area, the data base is inadequate due to many unknown factors.

For Model OH-58, the system effectiveness rate calculations are shown in Table 19. For wire strikes, the tail rotor is relatively less vulnerable. This is due to the fact that the tail rotor on the OH-58 is placed on the tailboom, unlike the UH-1 and AH-1 where the tail rotor is located on the vertical fin. Significant improvements are possible by treating the fuselage and controls area.

The system effectiveness rates indicate the potential that the obstacle strike protection devices have in protecting against wire and tree strikes. The studies conducted for Models UH-1, AH-1, and OH-58 indicate that some strike damage reduction can be achieved by protecting the fuselage through relatively simple modifications. For additional improvements, the tail rotor and main rotor protection will be required. These conclusions will be quantified in subsequent sections.

TABLE 18. OBSTACLE STRIKE SYSTEM EFFECTIVENESS CONSIDERATION FOR MODEL AH-1

Selected Concept	All Obstacles and All Mishaps			Tree Strike Accidents			Wire Strike Accidents			Wire Strike Mishaps		
	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %
1. Pyrotechnic Cutters on LE	48.6	48.2	23.4	14.3	40.0	5.7	25.0	90.0	22.5	N/A	90.0	N/A
2. Strike-tolerant M/R Tip	48.6	72.7	35.3	14.3	85.0	12.2	25.0	10.0	2.5		10.0	
3. Tail Rotor Shroud	16.7	75.8	12.7	57.1	75.0	42.8	25.0	80.0	20.0		80.0	
4. Strike-tolerant T/R Tip	16.7	66.0	11.0	57.1	75.0	42.8	25.0	20.0	5.0		20.0	
5. Faired-in Skid Landing Gear	3.6	30.6	1.1	I/D	20.0	-	I/D	85.0	-		85.0	
6. Wire Guides & Knife-edge Cutters	7.2	25.6	1.8	I/D	15.0	-	I/D	80.0	-		80.0	
7. Wire-Cutting Hub Shields	5.1	20.6	1.1	I/D	10.0	-	I/D	75.0	-		75.0	
8. LSC Wire Cutters for Canopy and Controls	5.1	21.4	1.1	I/D	10.0	-	I/D	80.0	-		80.0	

NOTES:
I/D Inadequate Data Base
N/A Not Analyzed
* Relative effectiveness is a composite number calculated by weighing tree and wire strike protection effectiveness by tree and wire strike incident numbers (87:17).
Eff. means Effectiveness

TABLE 19. OBSTACLE STRIKE SYSTEM EFFECTIVENESS CONSIDERATION FOR MODEL OH-58

Selected Concept	All Obstacles and All Mishaps			Tree Strike Accidents			Wire Strike Accidents			Wire Strike Mishaps		
	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %	Heli. Area Struck	Rel. Eff. %	Sys. Eff. %
1. Pyrotechnic Cutters on LE	58.7	53.7	31.5	N/A	4.0	N/A	16.0	90.0	14.4	13.0	90.0	11.7
2. Strike-tolerant M/R Tip	58.7	64.5	37.9		85.0		16.0	10.0	1.6	13.0	10.0	1.3
3. Tail Rotor Shroud	10.7	76.4	8.2		75.0		0.0	80.0	0.0	9.3	80.0	7.4
4. Strike-tolerant T/R Tip	10.6	59.9	6.4		75.0		0.0	20.0	0.0	9.3	20.0	1.9
5. Faired-in Skid Landing Gear	1.7	37.8	0.6		20.0		4.0	85.0	3.4	5.6	85.0	4.8
6. Wire Guides & Knife-edge Cutters	10.3	32.8	3.4		15.0		20.0	80.0	16.0	50.0	80.0	40.0
7. Wire-Cutting Hub Shields	13.6	27.8	3.8		10.0		28.0	75.0	21.0	13.0	75.0	9.8
8. LSC Wire Cutters for Canopy and Controls	13.6	29.2	4.0		10.0		20.0	80.0	16.0	13.0	80.0	10.4

NOTES:
I/D Inadequate Data Base
N/A Not Analyzed
* Relative effectiveness is a composite number calculated by weighing tree and wire strike protection effectiveness by tree and wire strike incident numbers (138:52).
Eff. means Effectiveness

6.4 POTENTIAL DAMAGE COST SAVINGS

Having selected the most promising concepts for tree and wire strike protection for helicopter rotors, fuselage, hub, and controls, the next logical step is to precisely define the potential damage cost savings for these concepts.

The potential cost reductions are computed as shown in Table 20. Three modification items are presented. The first modification, Mod Item 1, deals with fuselage and controls protection concepts incorporated on UH-1 helicopters. The minimum expected damage cost savings are calculated as follows. From Models UH-1, and AH-1 accident data, the damage costs are computed, which are then extrapolated to all the rotary wing helicopters for the period of 1972 through November 1977. Specifically, the system effectiveness rates were multiplied by the accident costs associated with wire and tree strike accidents. The expected damage cost savings are calculated from the minimum expected damage cost savings by using a multiplication factor. The multiplication factor of 2.63 is based on the fact that in about 62 percent of the helicopter accident cases, the helicopter area struck is not known.

The potential damage cost reductions for the remaining modification items for the tail and main rotor are similarly calculated. In the main rotor area, calculations have been made for strike-tolerant main rotor tips and for pyrotechnic cutters on the blade leading edge.

In order for these modification items to be compared in proper perspective, the initial installed cost ratings are also shown. A higher rating indicates lower installed cost. Consider Mod Item 1; the wire guides and LSC or mechanical wire cutters for canopy and controls, when incorporated on helicopters, have a potential of reducing the damage cost by $6.5 million during a period comparable to 1972 through November 1977. In terms of initial installed cost, this modification item has a favorable rating of 9.0. The rating is for an LSC wire cutter for canopy and controls, which is an expensive item. A mechanical cutter to perform the same function is expected to have higher initial installed cost rating at slightly lower system effectiveness.

Similarly, the tail rotor modification item has a potential of reducing damage costs by $7.4 million with an average installed cost rating of 5.0.

TABLE 20. STRIKE DAMAGE COST REDUCTION POTENTIAL

Strike Protection Concept Incorporated on Helicopter	Minimum Expected[1] Damage Cost Savings For a Period Comparable To 1972 thru Nov. 1977		Expected Cost Savings For a Period Comparable To 1972 thru Nov. 1977 (Estimated)[2]		Initial Installed Cost Rating[4]
	$ Million	% of Total	$ Million	% of Total	
Mod Item 1 - Fuselage & Controls					
Wire guides + LSC or mechanical wire cutters for canopy and controls	2.47	8.5	6.5	22.4	9.0
Mod Item 2 - Tail Rotor					
Tail rotor shroud or fan-in-fin	2.81	9.7	7.4	25.5	5.0
Mod Item 3 - Main Rotor					
Strike-tolerant M/R Tip and/or	2.14	7.4	5.6	19.6	10.0
Pyrotechnic Cutters on LE	2.16	7.5	5.7	19.7	4.5
			Total 25.2[3]		
					Max 10

NOTES: [1]Extrapolated for all Army rotary wing aircraft from the analysis of UH-1 and AH-1 data.
[2]Estimated costs are obtained from the minimum costs by accounting for the fact that in about 62% of the accidents the helicopter area struck was not known.
3Total actual damage cost was $28.9 million.
4Maximum rating is 10 (the higher the initial installed cost rating, the cheaper the cost of implementing the concept).

The potential damage cost savings on both promising main rotor concepts have been calculated as Mod Item 3. The strike-tolerant tip is expected to be very effective against tree strikes and has a very favorable cost rating of 10.0. The damage cost reduction potential associated with the strike-tolerant main rotor tip is about $5.6 million. The pyrotechnic cutters on the blade leading edge are effective against wire strikes with a potential damage cost savings of about $5.7 million and a poor initial installed cost rating of 4.5.

6.5 HELICOPTER MODIFICATION IMPLEMENTATION

The successive implementation of these modification items on a UH-1 helicopter is shown in Figures 35 through 37. Figure 38 is an artist's concept of a helicopter with complete obstacle-strike protection. A helicopter that might be designed in the future must incorporate some or all of these obstacle-strike protection design features. It should be pointed out that in most cases the proposed obstacle-strike protection concepts perform multiple functions.

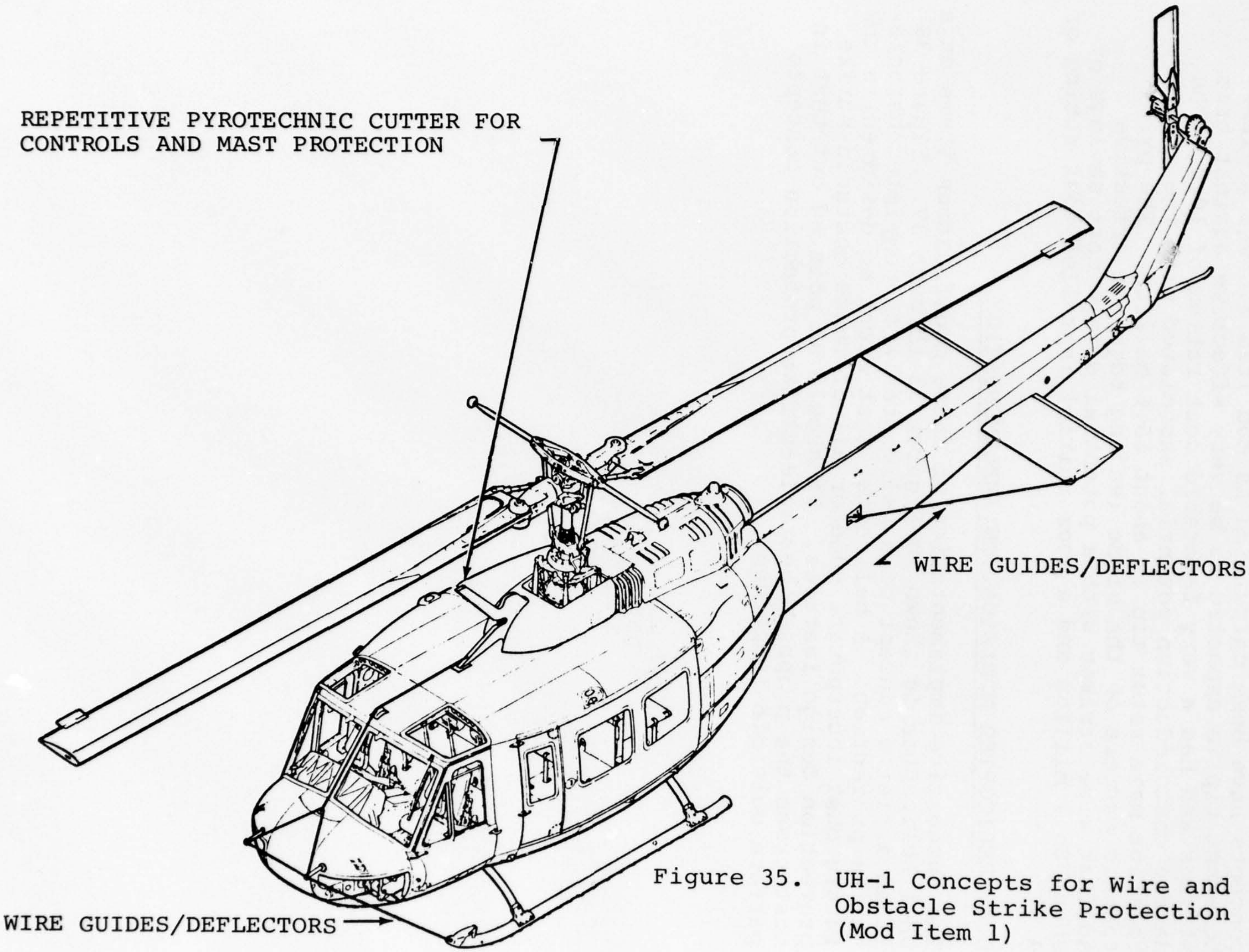


Figure 35. UH-1 Concepts for Wire and Obstacle Strike Protection (Mod Item 1)

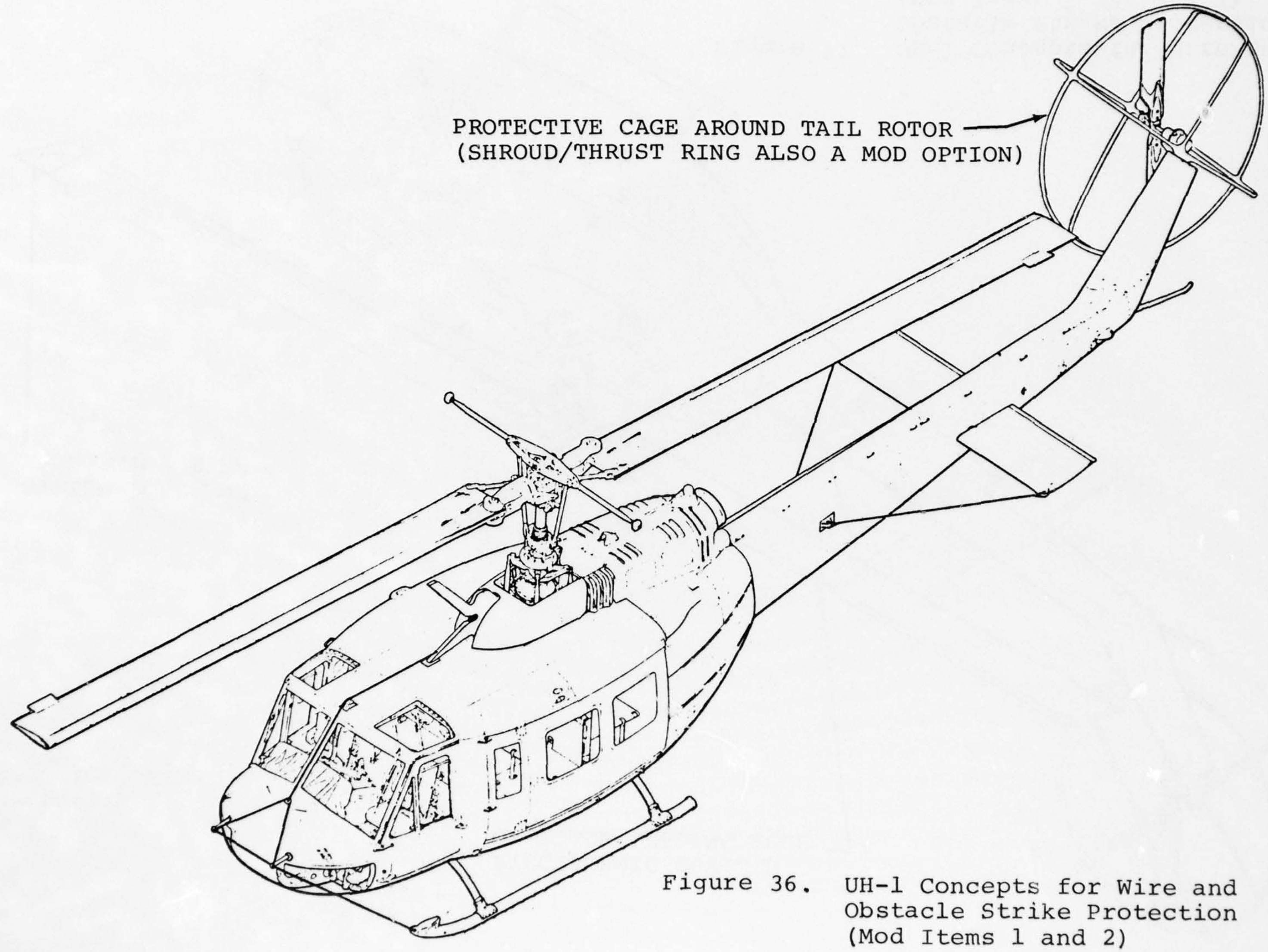


Figure 36. UH-1 Concepts for Wire and Obstacle Strike Protection (Mod Items 1 and 2)

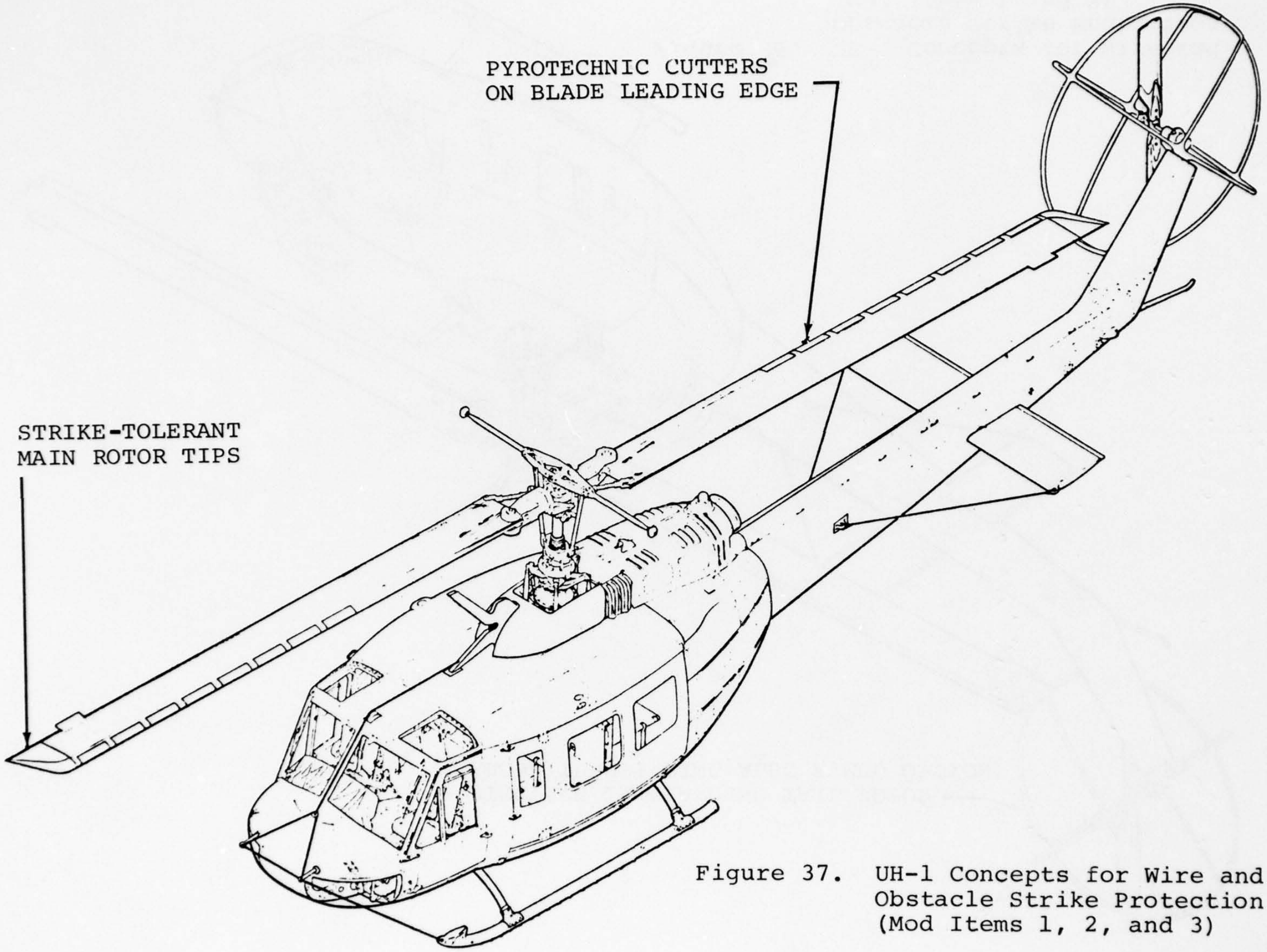


Figure 37. UH-1 Concepts for Wire and Obstacle Strike Protection (Mod Items 1, 2, and 3)

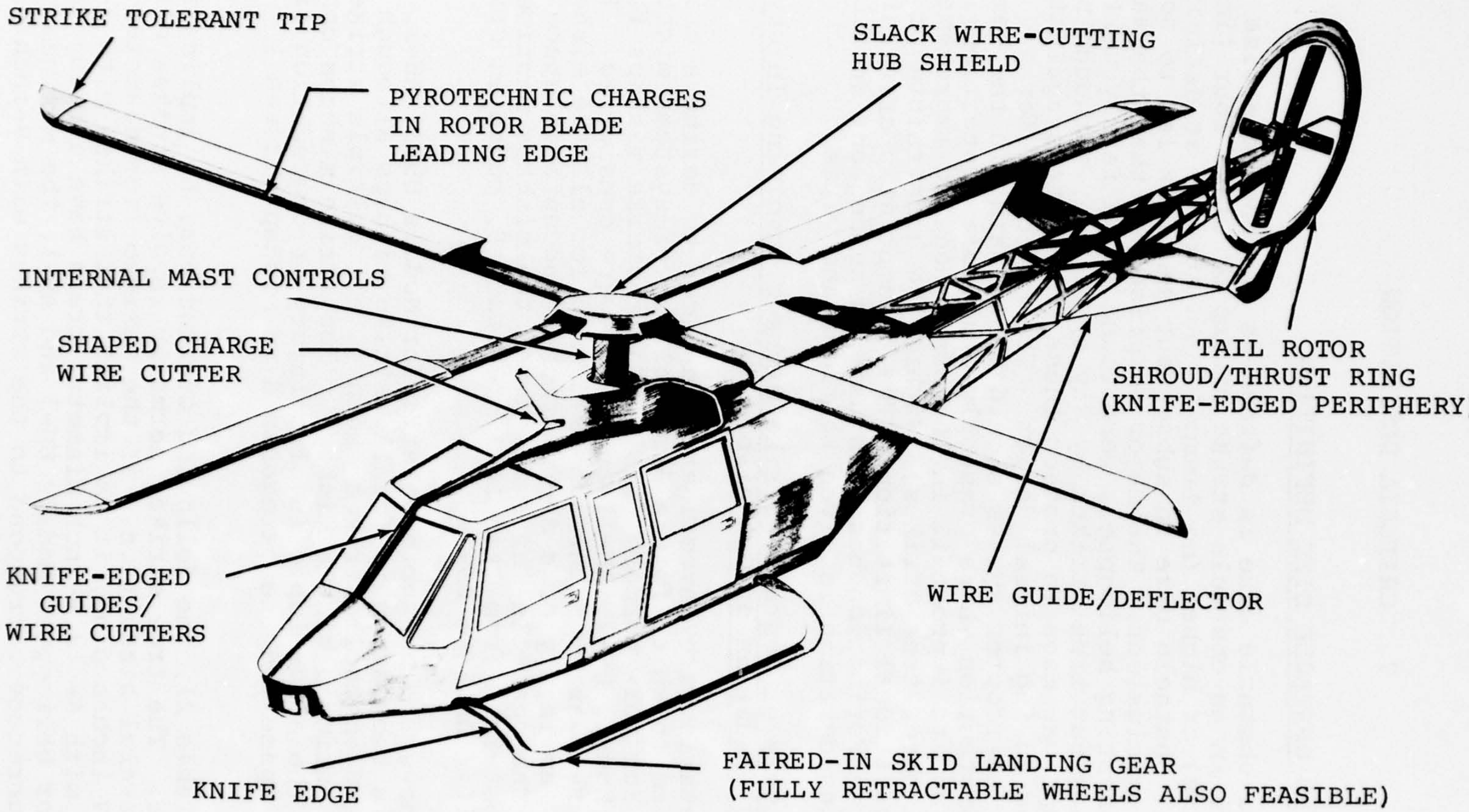


Figure 38. Concept Helicopter With Wire and Obstacle Strike Protection Concepts

7. CRITERIA DEFINITION

7.1 CRITICAL OBSTACLE SIZE DEFINITION

The critical obstacle size is defined as the obstacle size that results in an obstacle strike mishap of Class four (incidental damage) or higher (no damage). An Attempt at defining the critical obstacle size in subsequent sections led to some surprising conclusions. The major surprise was that the main rotors of existing helicopters were found to be fairly well protected against tree strikes by way of design, although no overt attempt was made to protect these helicopters against tree strikes during initial design. The objective for a future Army helicopter system should be to maintain the same degree of protection where presently available protection is acceptable and to improve it in the areas needing improvement (e.g., tail rotor tree strikes), within the constraints of cost and operational limitation. The attempt at a critical obstacle size definition has been made in subsequent sections. Separate consideration is given to trees and wires.

7.1.1 Analysis of Obstacle Strike Mishaps Involving Injury or Degradation of Occupiable Space

Obstacle details were investigated in order to define a critical tree size to which future Army helicopter systems might be designed. For this purpose, 115 obstacle strike mishaps for helicopter Models UH-1, AH-1, and OH-58 were considered. The period covered was 1971 through 1975, and for all the mishaps considered, an injury or a degradation of occupiable space occurred. The obstacle information for the mishaps mentioned above was obtained from Item (4C), "Obstacle", coded in Crash Survivability, DA Form 2397-6.

Table 21 shows the obstacle details for Models UH-1, AH-1, and OH-58. This tabulation is for 115 strike mishaps although there are 190 obstacle strikes shown (i.e., multiple strikes took place during a single mishap). The strike mishaps considered in the above table involve injury or degradation of occupiable space and are categorized in mishap classes 1 through 3.

Examining Table 21, the following conclusions, by implication, can be made. The tree strikes normally involve strikes with trees of several sizes (i.e., if the maximum tree diameter struck is 9 inches plus, it is implied that strikes with 3- to 6-inch and with 6- to 9-inch diameter trees have already taken place). For helicopter Models UH-1 and AH-1, the maximum number of occurrences correspond to the strikes with 9-inch plus

TABLE 21. OBSTACLE DETAILS FOR MISHAPS INVOLVING INJURY OR DEGRADATION OF OCCUPIABLE SPACE DURING THE PERIOD 1971 THROUGH 1975

Obstacle	Number of Strike Occurrences For Helicopter Models		
	UH-1	AH-1	OH-58
Rigid Structure	0	0	1
Wood Frame Bldg.	1	1	1
Boulders (0.5 - 1.0 ft dia)	5	0	5
Boulders (1.0 - 2.0 ft dia)	5	2	1
Boulders (2-ft plus dia)	4	1	1
Trees (3- to 6-in. dia)	12	4	10
Trees (6- to 9-in. dia)	17	7	9
Trees (9-in. plus dia)	20	9	7
Shrub Trees	15	4	5
Wires	8	3	9
Pole(s)	4	1	1
Others	11	2	4
Total	102	34	54

diameter trees. This implies that the probability of having a serious mishap is higher for bigger tree sizes (for tree sizes in the range of 3- to 6-inch and 6- to 9-inch diameter, a higher proportion of mishaps should be of nonserious nature). For Model OH-58, which is a lower gross weight helicopter, the maximum number of occurrences are for trees in the range of 3- to 6-inch diameter. Based on the above discussion, the conclusion is that the critical obstacle size should be in the range of 3- to 6-inch diameter.

7.1.2 Analysis of Mishaps of Class Four or Higher (No Damage

Again, tree strikes were considered first. Analysis of mishaps, Class four and higher, indicated that main rotor strikes involving tree size as large as 4 inches in diameter resulted, at worst, in incidental damage to UH-1 and AH-1 helicopters. The mishaps were, however, more serious when tail rotor strikes were involved. For example, a tail rotor strike with a 3.8-inch diameter tree resulted in a Class three (minor damage) mishap. For Model OH-58, which is a lower gross weight helicopter, the maximum tree sizes encountered in minor mishaps (Classes four through six) were found to be about 2 inches in diameter for the tail rotor.

The accident analysis conducted above indicates that for Models UH-1 and AH-1, the critical tree size for main rotor strikes might be 4 inches, while for tail rotor strikes a 3-inch diameter tree might be acceptable. For Model OH-58 main rotor strikes a critical tree size of 3-inch diameter seems reasonable.

A similar analysis to the one described above was conducted for wire strike cases. For Model AH-1, copper power lines (1/8- to 1/4-inch diameter), telephone wires, communication lines, etc., resulted in mishaps of Class four through six (incident damage through precautionary landing), while steel cables and high-power lines resulted in major damage or total loss. The tail rotor wire strikes were usually more severe.

For Model OH-58, 1/8- to 1/4-inch copper power lines, communication lines, and WD1 wire caused incidental damage at worst, while steel power lines resulted in total losses or major and minor damages. For Model OH-58, two mishaps were of particular interest. One involved a strike with 220 KV powerlines, while in the other mishap, a TOW missile wire (which is slack) was wrapped around the control tubes. Both of these mishaps resulted in incidental damage (Class four).

Based on the wire strike mishaps analysis, critical wire size is defined to be a 1/4-inch copper power line or up to 1/4-inch communication or telephone wire. Once again, if the tail rotor is involved in the strike, the mishaps might be more serious than they are for main rotor strikes.

7.1.3 Full-Scale Rotor Tree Strike Experiments

The tree strike experiments were not part of the contract tasks. The conclusions of the tests, however, are applicable towards defining critical tree size.

Figure 39 is a photograph of the rotor impact test stand at BHT's research testing facilities. The test stand is located in a whirl cage facility, and presently a BHT Model 206 size rotor system (Army equivalent Model OH-58) is mounted on it. The rotor is driven by a 75 hp electric motor that can be clutched in or out. The blades are stress and strain gauge instrumented, and the blade load data in the rotating system are transferred to the fixed system using a 13-channel slip-ring. A slider mechanism, which is attached to the main stand, is used to propel telephone poles and tree trunks into the tippath plane. The slider mechanism is bungee powered and can be released at a selected rotor azimuth.

The tests were conducted at about 320 rpm (design rpm is 394). Figure 40 shows 1-, 3-, 4- and 5-inch-diameter pine trees as chopped by the rotor. There was no visible damage to the rotor up to a diameter of 4 inches. After a 5-inch-diameter tree strike, wrinkles in blade trailing edges were found, although there was no damage to the spar structure. The wrinkles are shown in Figure 41. Since the strikes were simulated at ideal contact orientation during the experiments, the conclusions may not be directly applicable to the Model OH-58 main rotor in flight. However, the conclusion arrived at in previous sections, regarding a 4-inch diameter being the critical tree size for helicopter Models AH-1 and UH-1 main rotor strikes, seems to be valid.

7.2 APPROACH TO CRITERIA DEFINITION

The most obvious approach to criteria definition will be to identify the critical obstacle hazards, and then to define the critical obstacle size to which the helicopter should be designed. However, a definition is complicated by two factors. First, critical obstacle size depends upon the helicopter area being struck (for example, the critical tree size is smaller for the tail rotor than it is for the main rotor). The second factor deals with implementation of obstacle strike protection design changes on the helicopter. Some of the obstacle strike protection design changes in a specific helicopter area will

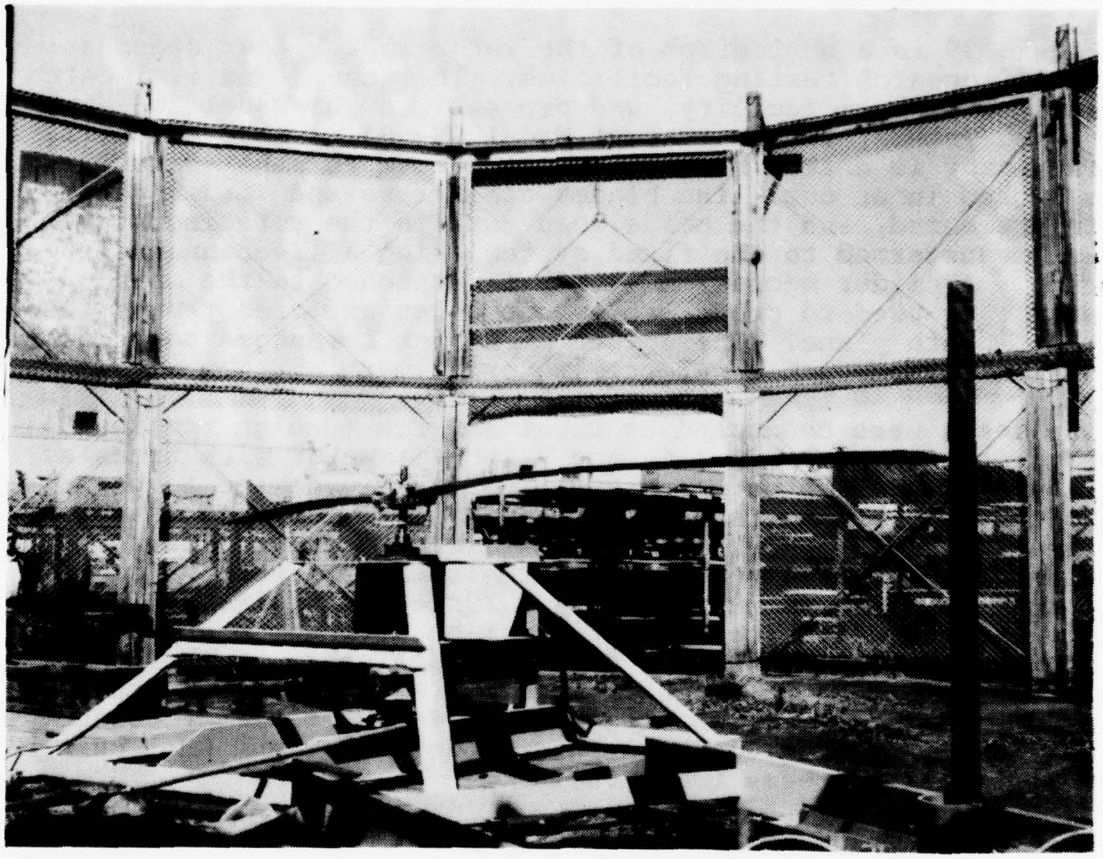


Figure 39. Rotor Impact Test Stand at BHT Research Testing Facilities

Figure 40. Pine Trees Chopped by the Rotor, Largest Diameter is 5 inches

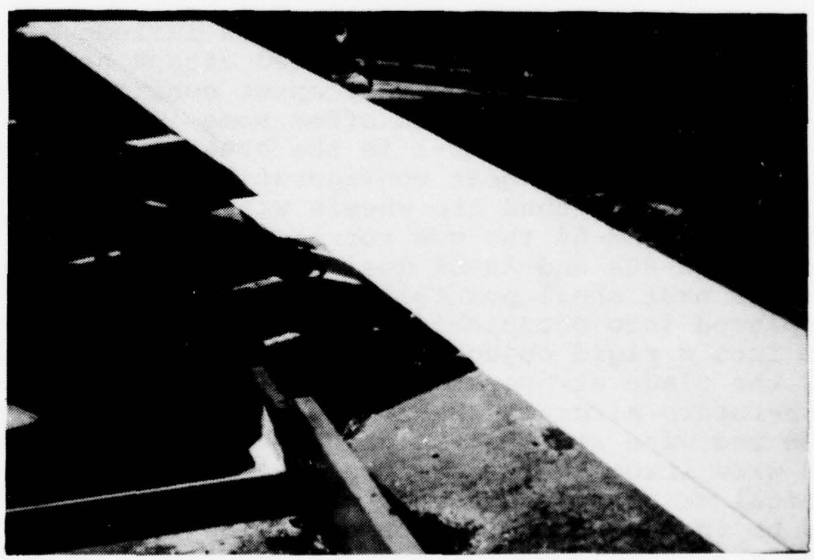


Figure 41. Wrinkles in Blade Trailing Edge After 5-Inch-Diameter Strike

make it tolerant of most obstacle strikes in that area, but may not raise the critical obstacle size for the aircraft as a whole. (For example, incorporating a shroud on the tail rotor will make that area very tolerant of tree and wire strikes, but will not change the critical size with respect to other areas of the aircraft.) In subsequent sections, the criteria are defined for current, near-future, and future Army helicopter systems.

7.3 CRITERIA DEFINITION FOR EXISTING HELICOPTER SYSTEMS

Based upon the previous concept comparisons and critical obstacle definitions for helicopter Models UH-1, AH-1, and OH-58 (see Figures 42 through 44), cost effective retrofit actions can significantly improve the obstacle strike tolerance of current Army helicopters and thereby improve their survivability. Fuselage and landing gear wire guides, canopy-mounted pyrotechnic or mechanical wire cutters, shielding of main rotor controls, and tail rotor guards should be implemented, at least in part. Preliminary calculations indicate that these retrofit items can be implemented at minimal cost with little effect on helicopter weight and performance.

7.4 CRITERIA DEFINITION FOR NEAR-FUTURE ARMY HELICOPTER SYSTEMS

The near-future Army helicopter systems include a utility helicopter, Model UH-60A, and an advanced attack helicopter, Model AH-64. A general review of helicopter configurations indicates that these helicopter systems offer some improvement over the current Models UH-1 and AH-1 in the area of obstacle strike protection. The landing gear configurations are such that wires may be deflected around the wheels without becoming entangled, though for the AH-64 the gun turret is a formidable wire snag threat. A UH-60A and AH-64 design specification requires that "The rotor mast shall not fail and the transmission shall not be displaced into occupiable space when the main rotor blades impact into a rigid object 8 inches in diameter on the outer 10% of the blade at operational rotor speed." The main rotors of near-future aircraft should fare better than current models in tree and wire strikes. Also, cleaner hub designs should reduce wire snaggings. Nevertheless, fuselage wire guides, mechanical or pyrotechnic wire cutters, and tail rotor guards should be incorporated. If these strike tolerance designs are cost effective for current Army helicopters, their cost effectiveness for near-future, high-cost helicopters would be substantially greater.

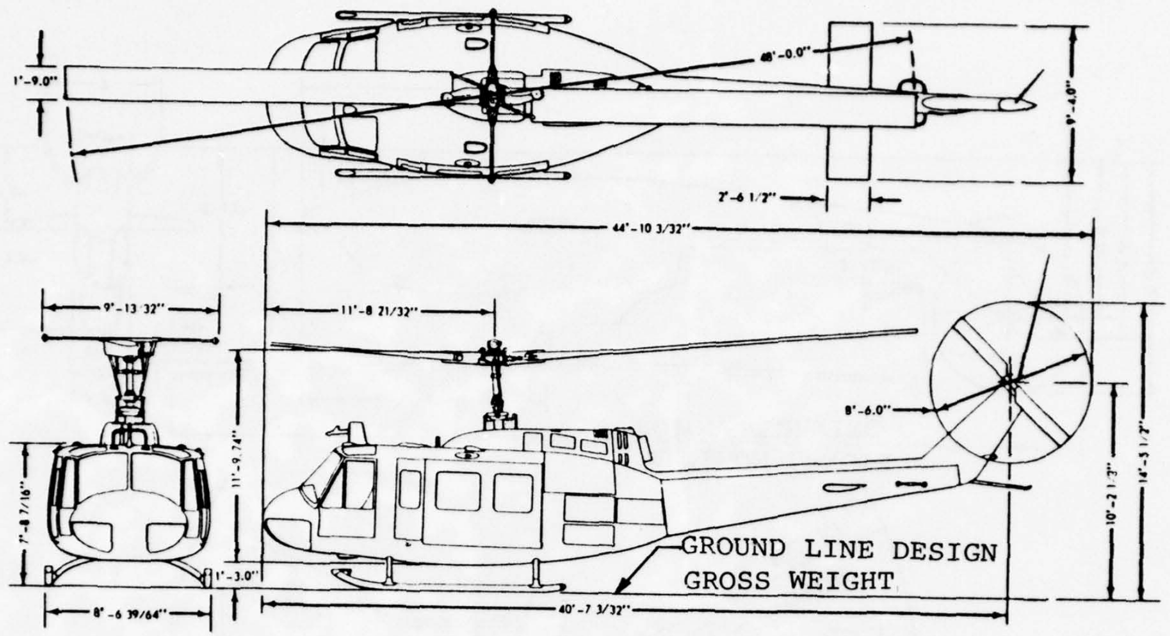


Figure 42. Helicopter UH-1D/H Three View-Drawing

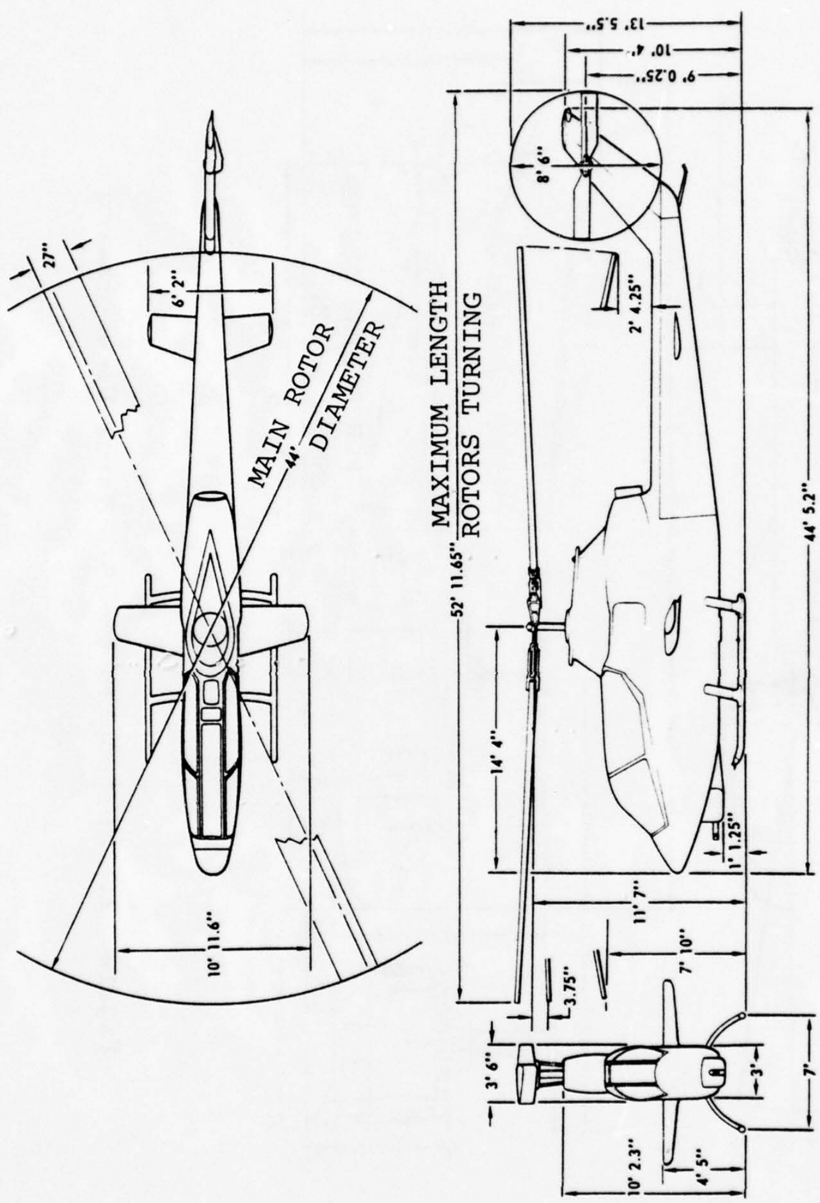


Figure 43. Helicopter AH-1G Three View Drawing

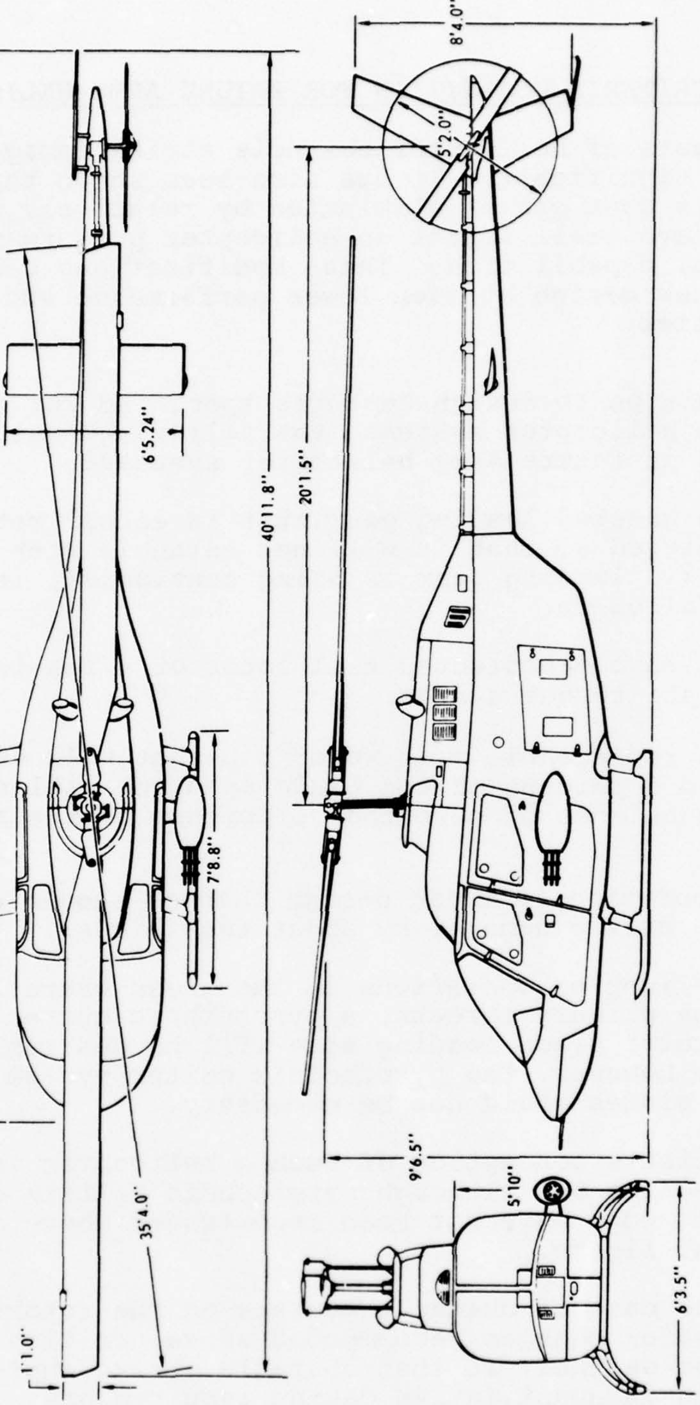


Figure 44. Helicopter OH-58A Three-View Drawing

7.5 CRITERIA DEFINITION FOR FUTURE ARMY HELICOPTER SYSTEMS

The costs of helicopter obstacle strike damage have been shown to be significant. It has also been shown that a large portion of this cost can be eliminated by relatively minor retrofits that have small impact on helicopter performance and operational capabilities. These modifications can be incorporated on a new design at even lower performance and operational penalties.

In addition to design features specified for existing and near-future helicopter systems, the following features should be included in future Army helicopter systems:

- A wheeled landing gear that is either retractable or designed so that it will not entangle with wires. If a skid landing gear is being considered, it should be faired-in.

- A shroud-protected tail rotor or a fan-in-fin type of anti-torque system.

- A replaceable main rotor tip that will deflect about 3 to 5 percent of the blade span but will not cause an unbalance of more than 1 percent of the blade mass.

Incorporation of these design changes should reduce the obstacle strike damages by about two-thirds.

For helicopter operations in the areas where large size wires are the primary threats, a pyrotechnic cutter system on the main rotor blade leading edge will be desirable. For smaller wires, however, the pyrotechnic cutter system on the main rotor blades would not be necessary.

An artist's conception of such a helicopter is shown in Figure 38, section 6. Although pyrotechnic cutters on the blade leading edge have not been recommended above, they are shown in that figure.

For the case of obstacle strikes on the rotors, in addition to the design changes recommended above, critical obstacle sizes must be defined, so that obstacle strike improvements can be related to quantitative design requirements.

8. CONCLUSIONS

1. The cost related to obstacle strike mishaps is a significant portion of the Army helicopter life-cycle cost. Based on the data for the period 1971 through November 1977 for all Army rotary wing aircraft, the aircraft damage cost is about $3.40 per flight hour. During the same period, there were 100 fatalities and 250 injuries.

2. About 14 percent of all the obstacle strike mishaps are classified as accidents. These accidents account for 88 percent of the damage cost. The most commonly encountered obstacles were trees and wires. Although tree strikes are four times as frequent as wire strikes, more major accidents and fatalities result from wire strikes.

3. Most of the obstacle strike mishaps occurred during NOE training missions. In most cases, the helicopters were flying at low altitude (0 - 50 feet) and at low speeds (0 - 15 knots) just before the strike. Most of the strikes occurred during the daytime and the weather was not a factor.

4. For all mishap classes and for all obstacles, the main rotor was most commonly struck. A high proportion of wire strikes occurred on the fuselage. In tree strike accidents the strikes were distributed between main and tail rotor.

5. Several design concepts to improve the obstacle strike tolerance of major helicopter areas were proposed. A comparative analysis indicated fuselage wire guides to be most effective for lower fuselage protection, while a pyrotechnic or mechanical cutter was found to be most effective for canopy and controls. A shroud or a fan-in-fin was found to be most effective in protecting the tail rotor area. A strike-tolerant main rotor tip was judged most effective against main rotor tree strikes; wire strike protection could be achieved with a pyrotechnic cutter on the blade leading edge.

6. The design changes to protect fuselage and controls can be incorporated on existing helicopter systems through retrofit in a cost-effective manner (damage cost savings are expected to offset engineering change costs).

7. Obstacle strike protection of future Army helicopter systems can be enhanced through application of the proposed design concepts for rotors, fuselage, and controls. This will enable Army helicopters to conduct all-weather daytime and nighttime NOE operations with a greatly reduced possibility of obstacle strike damage. The design concepts can be implemented on future helicopters in a cost-effective manner if the concepts are incorporated in initial design phases.

9. RECOMMENDATIONS

1. During the course of this study, about 1000 mishaps were reviewed. The accident summary sheets studied for this program sometimes did not contain sufficient details of the helicopter areas involved and of the obstacles that were encountered. Additional effort in obtaining and reviewing these details was not expended due to the limited scope of the study. A program to study the details of helicopter strike areas and to obtain obstacle descriptions for obstacle strike accidents is recommended.

2. The fabrication and functional testing of the following concepts is recommended. The concepts are listed in the order of recommended priority.

   I. Wire Guides and Linear Shaped Charge Cutters for Canopy and Controls

   II. Strike-Tolerant Main Rotor Tips

   III. Shrouded Tail Rotor

   IV. Pyrotechnic Cutters on Blade Leading Edges

A limited amount of testing has been done on some of the concepts recommended above. Full-scale functional testing, however, will be helpful in proving and optimizing the concepts.

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APPENDIX A
MISHAP SUMMARIES

TABLE A-1. AH-1/TH-1 MISHAP SUMMARY
(USAAAVS)

	ALL MISHAP OCCURRENCES		OBSTACLE STRIKES ONLY	
YEAR	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]
1971	61	461	4	13
1972	27	242	2	10
1973	22	250	6	29
1974	11	265	3	29
1975	13	314	2	28
1976	14	235	3	21
(10 NOV) 1977	8	245	1	21
TOTAL	156	2012	21	151

OBSTACLE STRIKES INVOLVED IN:
13.46% OF ACCIDENTS
7.50% OF MISHAPS

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

TABLE A-2. CH-47 MISHAP SUMMARY
(USAAAVS)

	All Mishap Occurrences		Obstacle Strikes Only	
YEAR	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]
1971	20	355	1	18
1972	3	169	0	3
1973	1	162	0	4
1974	1	195	0	2
1975	4	222	0	9
1976	1	171	0	9
NOV 1977	4	183	1	9
TOTAL	34	1457	2	54

OBSTACLE STRIKES INVOLVED IN:
5.88% OF ACCIDENTS
3.71% OF MISHAPS

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

TABLE A-3. OH-6A MISHAP SUMMARY
(USAAAVS)

	ALL MISHAP OCCURRENCES		OBSTACLE STRIKES ONLY	
YEAR	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]
1971	74	341	11	31
1972	33	111	6	18
1973	6	77	1	7
1974	5	71	1	2
1975	4	58	0	3
1976	2	27	0	1
NOV 1977	2	38	0	2
TOTAL	126	723	19	64

OBSTACLE STRIKES INVOLVED IN:
15.08% OF ACCIDENTS
8.85% OF MISHAPS

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

TABLE A-4. OH-58A MISHAP SUMMARY
(USAAAVS)

YEAR	ALL MISHAP OCCURRENCES: NO. OF ACCIDENTS[1]	ALL MISHAP OCCURRENCES: NO. OF MISHAPS[2]	OBSTACLE STRIKES ONLY: NO. OF ACCIDENTS[1]	OBSTACLE STRIKES ONLY: NO. OF MISHAPS[2]
1971	56	338	12	25
1972	31	387	13	32
1973	23	480	5	34
1974	22	508	5	34
1975	14	599	1	48
1976	21	367	8	45
(18 NOV) 1977	17	354	10	49
TOTAL	184	3033	54	266

OBSTACLE STRIKES INVOLVED IN:
29.35% OF ACCIDENTS
8.77% OF MISHAPS

[1]ACCIDENTS: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

TABLE A-5. TH-55 MISHAP SUMMARY
(USAAAVS)

	ALL MISHAP OCCURRENCES		OBSTACLE STRIKES ONLY	
YEAR	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]
1971	25	227	3	3
1972	5	56	0	0
1973	8	69	2	2
1974	22	162	1	1
1975	7	128	0	2
1976	4	89	1	1
NOV 1977	7	55	0	0
TOTAL	78	786	7	9

OBSTACLE STRIKES INVOLVED IN:
8.97% OF ACCIDENTS
1.14% OF MISHAPS

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

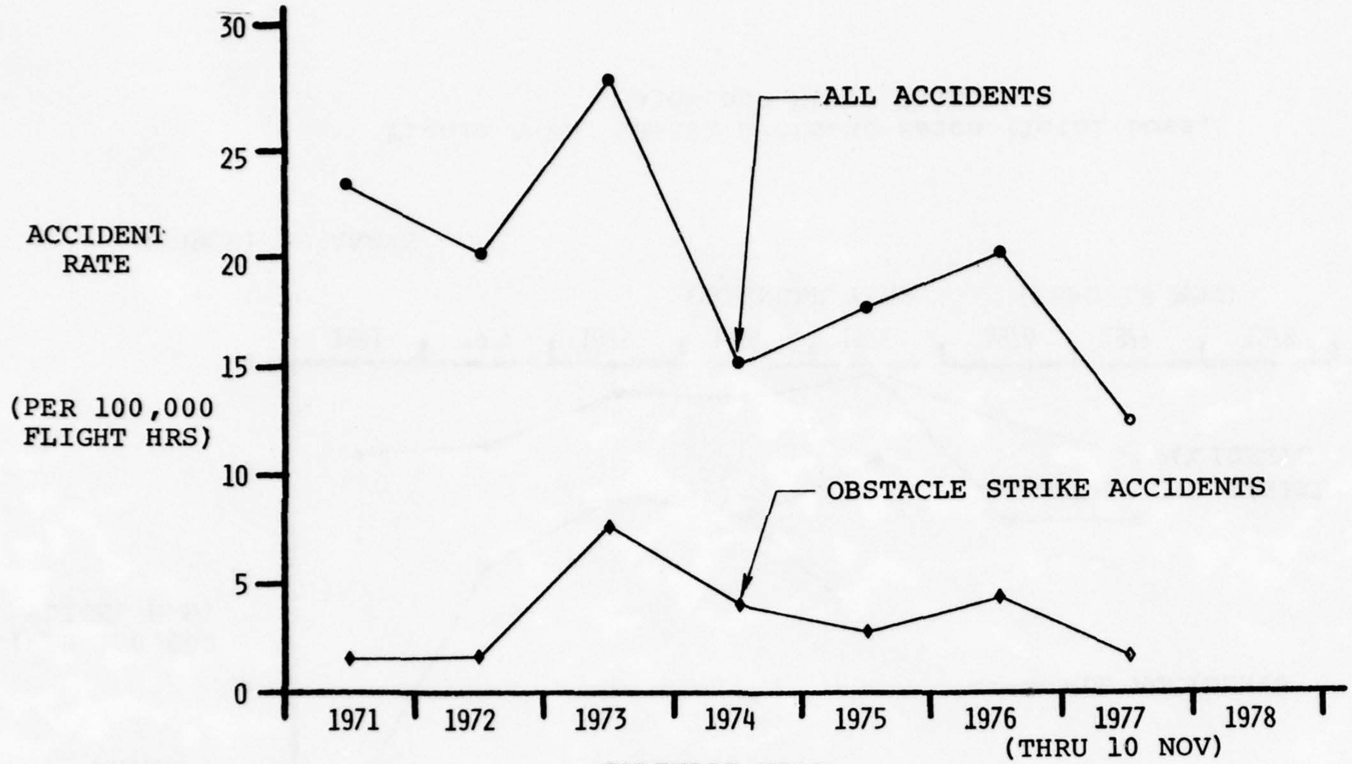
TABLE A-6. UH-1 (ALL) MISHAP SUMMARY
(USAAAVS)

	ALL MISHAP OCCURRENCES		OBSTACLE STRIKES ONLY	
YEAR	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]	NO. OF ACCIDENTS[1]	NO. OF MISHAPS[2]
1971	216	2105	42	227
1972	74	1215	11	63
1973	36	1123	2	46
1974	37	1301	6	48
1975	41	1342	12	72
1976	38	1126	6	90
NOV 1977	26	1015	4	57
TOTAL	468	9227	83	603

OBSTACLE STRIKES INVOLVED IN:
17.74% OF ACCIDENTS
6.54% OF MISHAPS

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS



SOURCE: USAAAVS

Figure A-1. AH-1/TH-1 Accident Rates (Total Loss, Major and Minor Damage)

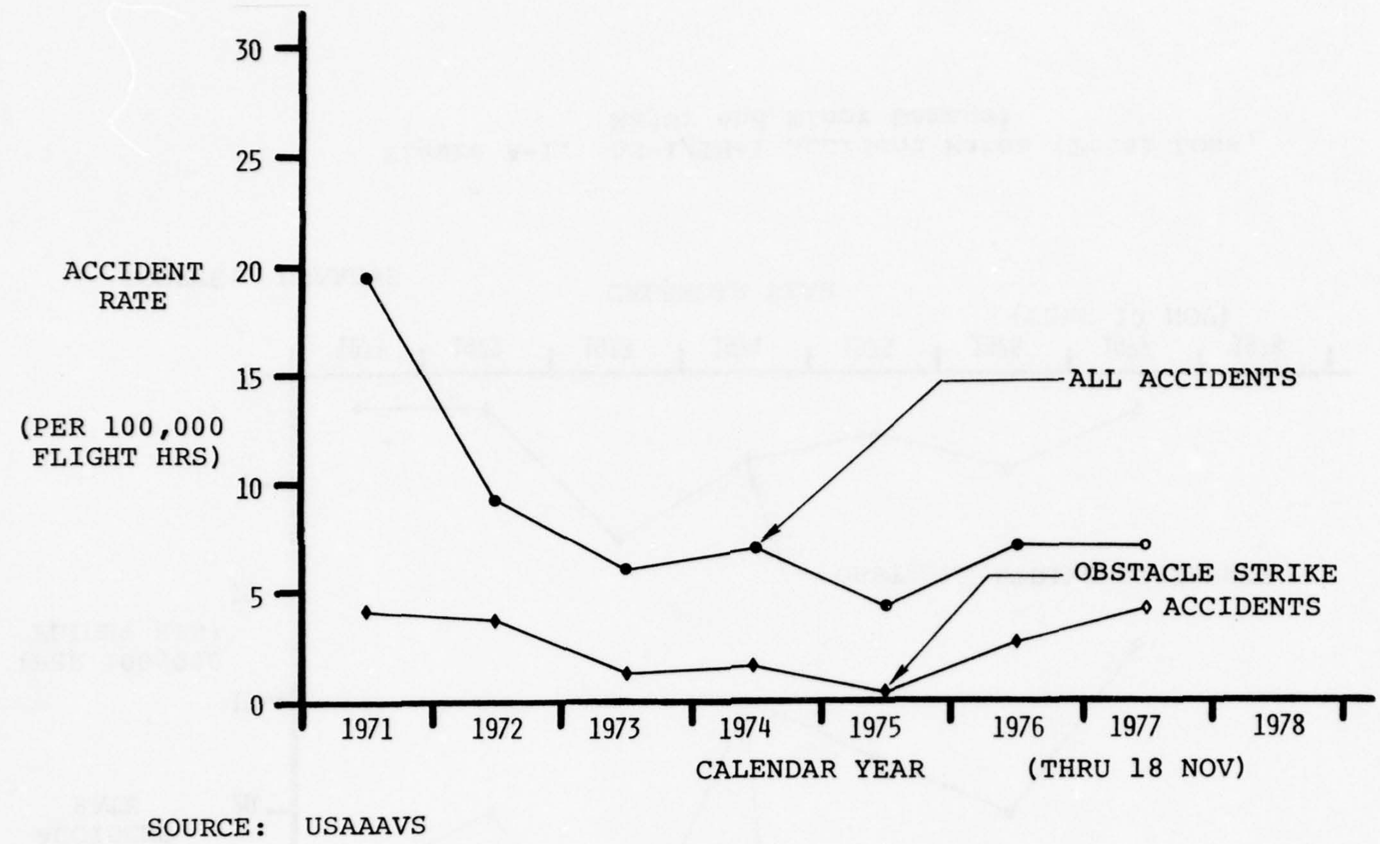
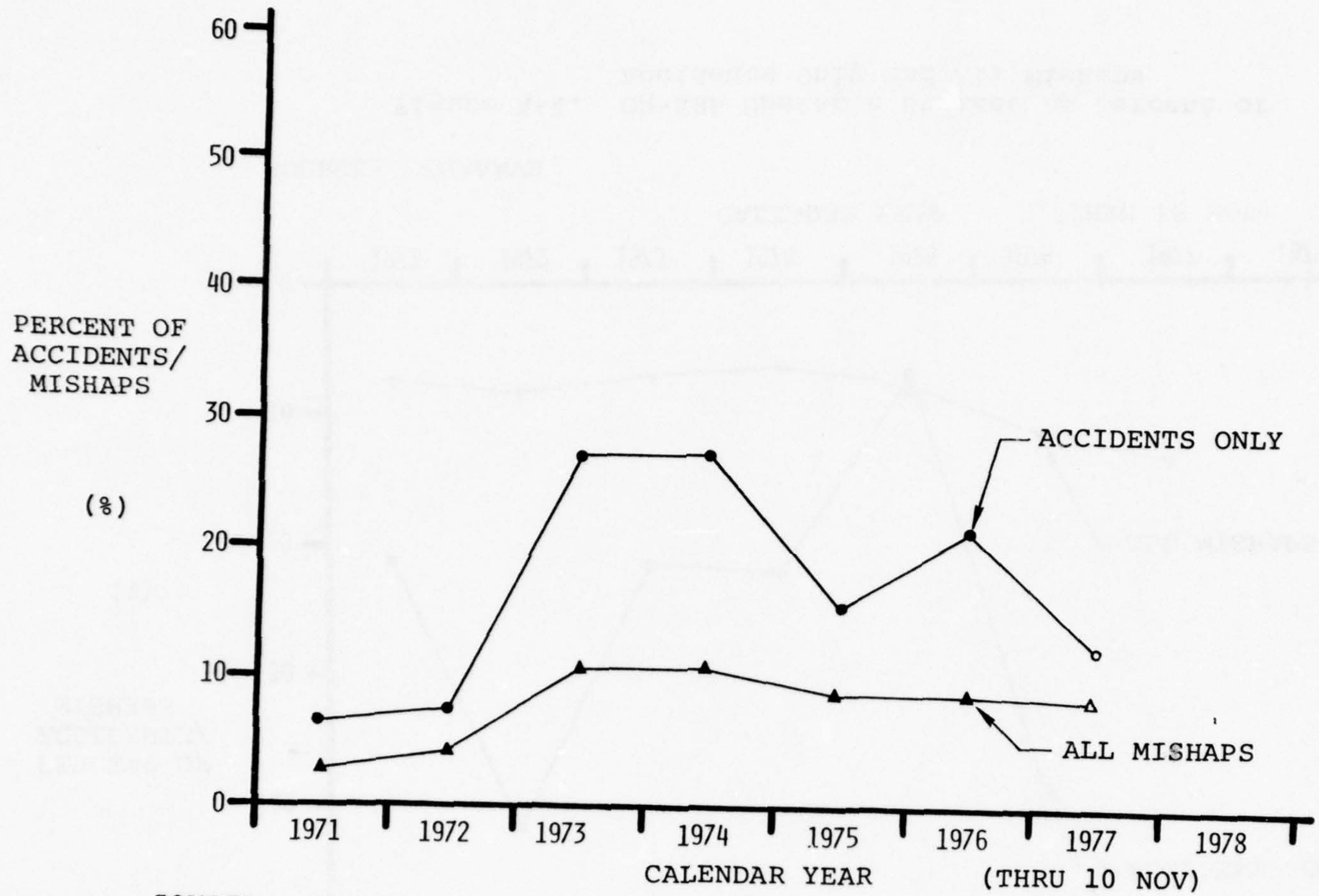
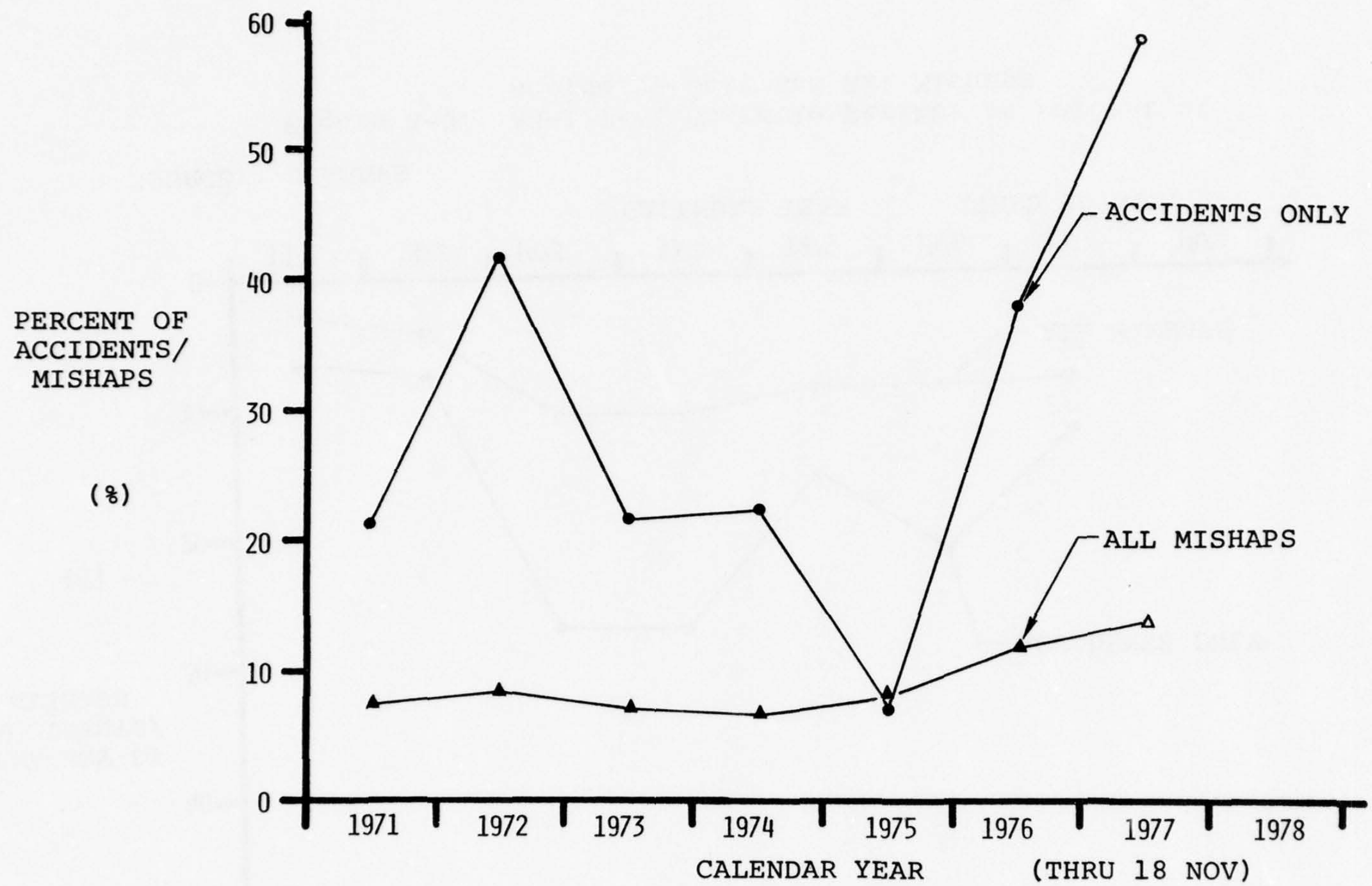


Figure A-2. OH-58A Accident Rates (Total Loss, Major and Minor Damage)



SOURCE: USAAAVS

Figure A-3. AH-1/TH-1 Obstacle Strikes as Percent of Accidents Only and All Mishaps



SOURCE: USAAAVS

Figure A-4. OH-58A Obstacle Strikes As Percent of Accidents Only and All Mishaps

TABLE A-7. AH-1 OBSTACLE STRIKE COSTS (USAAAVS)

	ACCIDENTS ONLY[1]			ALL MISHAPS[2]		
YEAR	NUMBER	COST ($)	AVERAGE COST ($)	NUMBER	COST ($)	AVERAGE COST ($)
1971	4	1,515,874	378,968	13	1,553,870	119,528
1972	2	688,799	344,400	10	720,930	72,093
1973	6	2,241,500	373,583	29	2,313,526	79,777
1974	3	1,033,929	344,643	29	1,140,883	39,341
1975	2	186,365	93,182	28	313,727	14,939
1976	3	282,452	94,150	21	422,903	20,138
1977 (NOV)	1	267,866	267,866	21	407,744	19,416
TOTAL	21	6,216,785	296,037	151	6,873,583	45,520

[1] ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2] MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

AVERAGE COST PER YEAR:

ACCIDENTS ONLY: $898,812

ALL MISHAPS: $993,771

TABLE A-8. CH-47 OBSTACLE STRIKE COSTS
(USAAAVS)

	Accidents Only[1]			All Mishaps[2]		
YEAR	NUMBER	COSTS ($)	AVERAGE COST ($)	NUMBER	COST ($)	AVERAGE COST ($)
1971	1	1,063,448	1,063,448	18	1,366,742	759,302
1972	0	0	0	3	46,932	15,644
1973	0	0	0	4	15,556	3,889
1974	0	0	0	2	54,000	27,000
1975	0	0	0	9	228,124	25,347
1976	0	0	0	9	317,181	35,242
1977 (NOV)	1	3,024,417	3,024,417	9	3,374,816	374,980
TOTAL	2	4,087,865	2,043,932	54	5,403,351	100,062

[1] ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2] MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

AVERAGE COST PER YEAR:

ACCIDENTS ONLY: $591,017

ALL MISHAPS: $781,207

TABLE A-9. OH-6A OBSTACLE STRIKE COSTS (USAAAVS)

	ACCIDENTS ONLY[1]			ALL MISHAPS[2]		
YEAR	NUMBER	COST ($)	AVERAGE COST ($)	NUMBER	COST ($)	AVERAGE COST ($)
1971	11	1,076,780	97,889	31	1,132,484	36,532
1972	6	349,934	58,322	18	379,382	21,077
1973	1	8,506	8,506	7	20,262	2,895
1974	1	125,821	125,821	2	127,221	63,610
1975	0	0	0	3	8,967	2,989
1976	0	0	0	1	0	0
1977 (NOV)	0	0	0	2	6,770	3,385
TOTAL	19	1,561,041	82,160	64	1,675,086	26,173

[1] ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2] MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

AVERAGE COST PER YEAR:

ACCIDENTS ONLY: $225,693

ALL MISHAPS: $242,181

TABLE A-10. OH-58A OBSTACLE STRIKE COSTS (USAAAVS)

YEAR	ACCIDENTS ONLY[1] NUMBER	COST ($)	AVERAGE COST ($)	ALL MISHAPS[2] NUMBER	COST ($)	AVERAGE COST ($)
1971	12	578,171	48,181	25	603,485	24,139
1972	13	1,094,611	84,201	32	1,149,933	35,935
1973	5	757,825	151,565	34	798,317	23,480
1974	5	226,249	45,250	34	291,637	8,578
1975	1	5,000	5,000	48	104,602	2,179
1976	8	1,045,222	130,653	44	1,165,075	26,479
1977 (NOV)	10	608,378	60,838	49	752,839	15,364
TOTAL	54	4,315,456	79,916	266	4,865,888	18,293

[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

AVERAGE COST PER YEAR:

ACCIDENTS ONLY: $623,921

ALL MISHAPS: $702,201

TABLE A-11. TH-55A OBSTACLE STRIKE COSTS (USAAAVS)

	ACCIDENTS ONLY[1]			ALL MISHAPS[2]		
YEAR	NUMBER	COST ($)	AVERAGE COST ($)	NUMBER	COST ($)	AVERAGE COST ($)
1971	3	63,615	21,205	3	63,615	21,205
1972	0	0	0	0	0	0
1973	2	71,321	35,660	2	71,321	35,660
1974	1	35,590	35,590	1	35,590	35,590
1975	0	0	0	2	393	196
1976	1	35,590	35,590	1	35,590	35,590
1977 (NOV)	0	0	0	0	0	0
TOTAL	7	206,611	29,445	9	206,509	22,945

[1] ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2] MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

AVERAGE COST PER YEAR:

ACCIDENTS ONLY: $29,800

ALL MISHAPS: $29,856

TABLE A-12. UH-1D/H OBSTACLE STRIKE COSTS (USAAAVS)

YEAR	ACCIDENTS ONLY[1] NUMBER	COST ($)	AVERAGE COST ($)	ALL MISHAPS[2] NUMBER	COST ($)	AVERAGE COST ($)
1971	36	5,254,122	145,948	213	5,984,657	28,097
1972	10	1,177,966	117,797	61	1,370,689	22,470
1973	2	415,165	207,582	42	516,400	12,295
1974	4	744,583	186,146	45	844,533	11,476
1975	11	2,314,383	210,398	70	2,438,304	34,833
1976	6	3,193,740	532,290	83	3,453,705	41,611
1977(26 NOV)	4	1,901,486	475,372	55	2,159,097	39,256
TOTAL	73	15,001,445	205,499	569	16,767,385	29,468

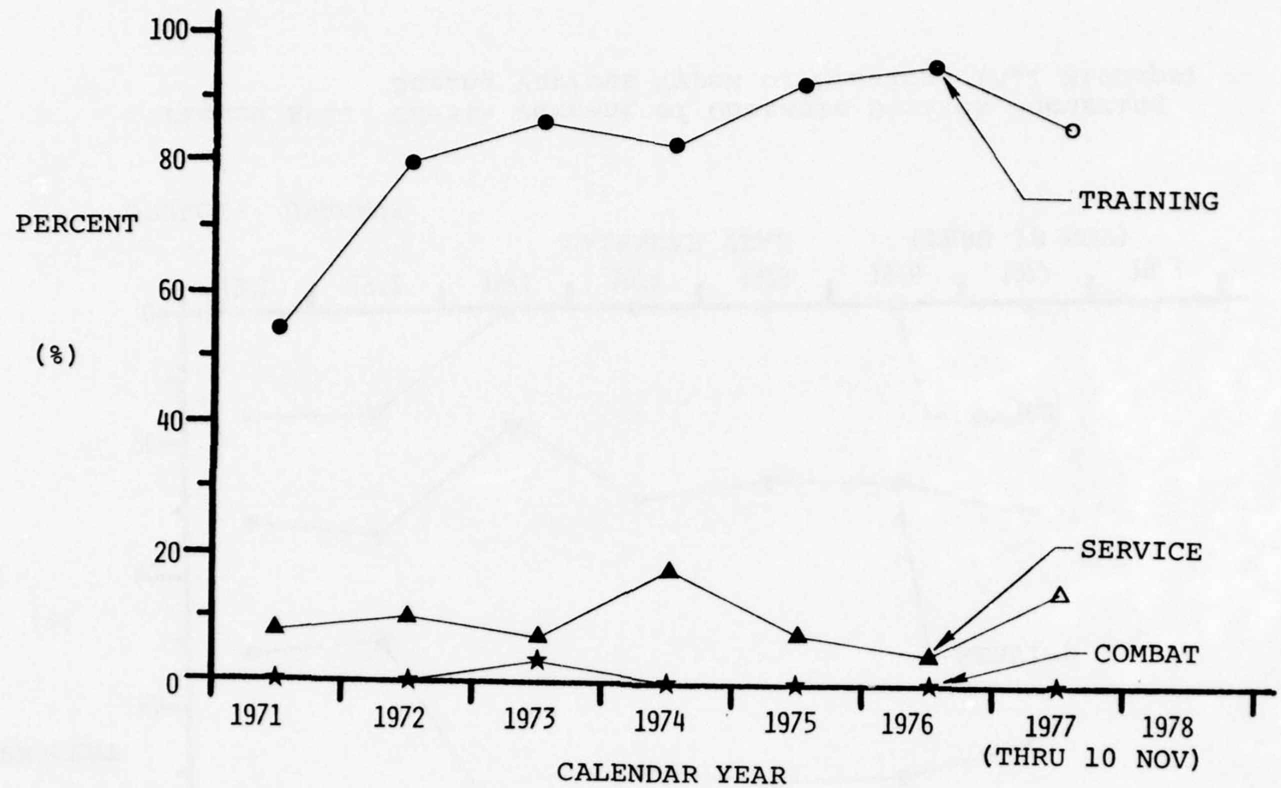
[1]ACCIDENT: TOTAL LOSS, MAJOR, MINOR DAMAGE

[2]MISHAP: TOTAL LOSS, MAJOR, MINOR, INCIDENT, FORCED AND PRECAUTIONARY LANDINGS

AVERAGE COST PER YEAR:

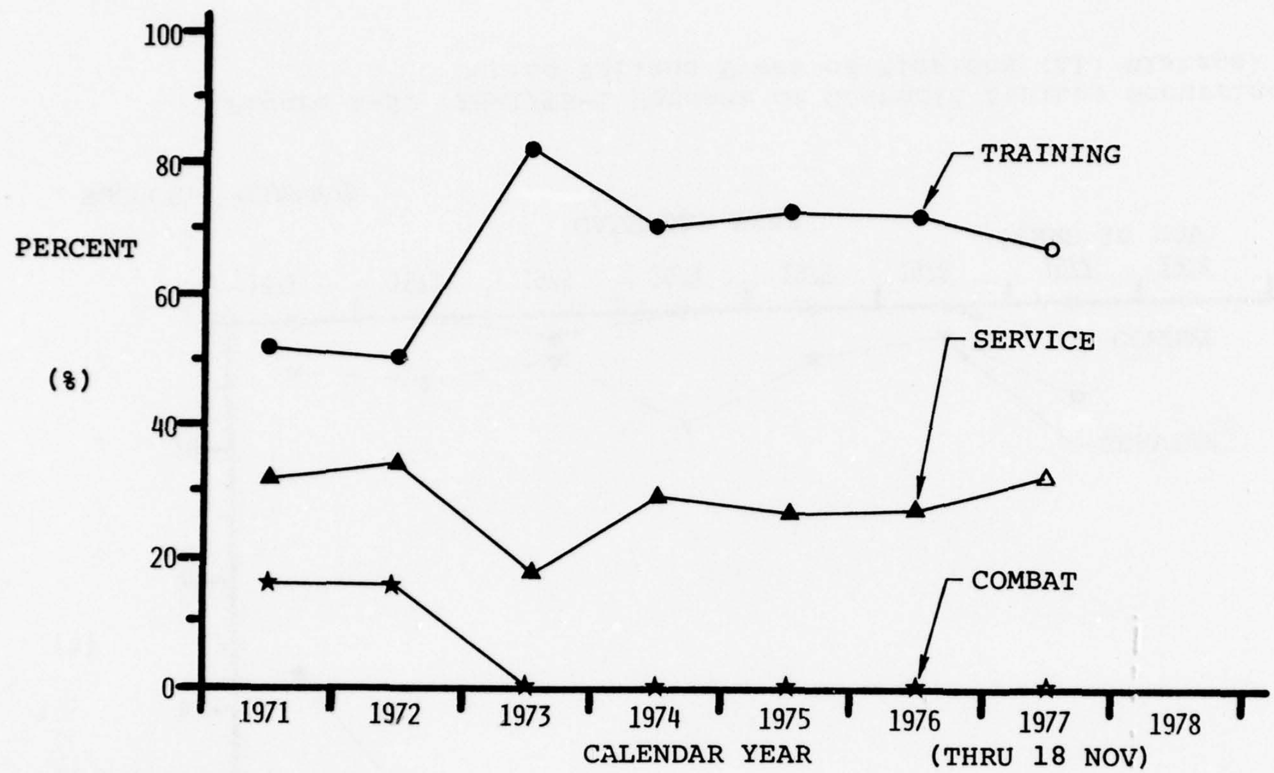
ACCIDENT ONLY: $2,168,884

ALL MISHAPS: $2,424,200



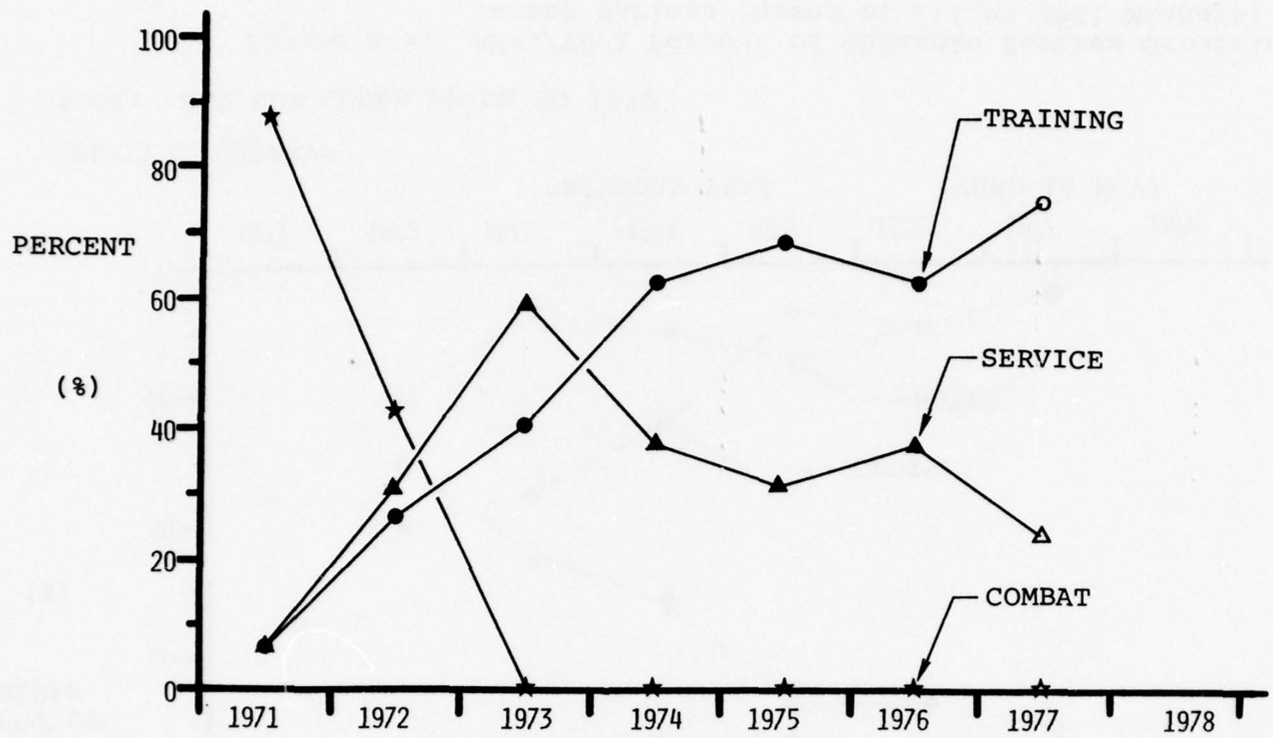
SOURCE: USAAAVS

Figure A-5. AH-1/TH-1 Percent of Obstacle Strikes Occurring During Various Types of Missions (All Mishaps)



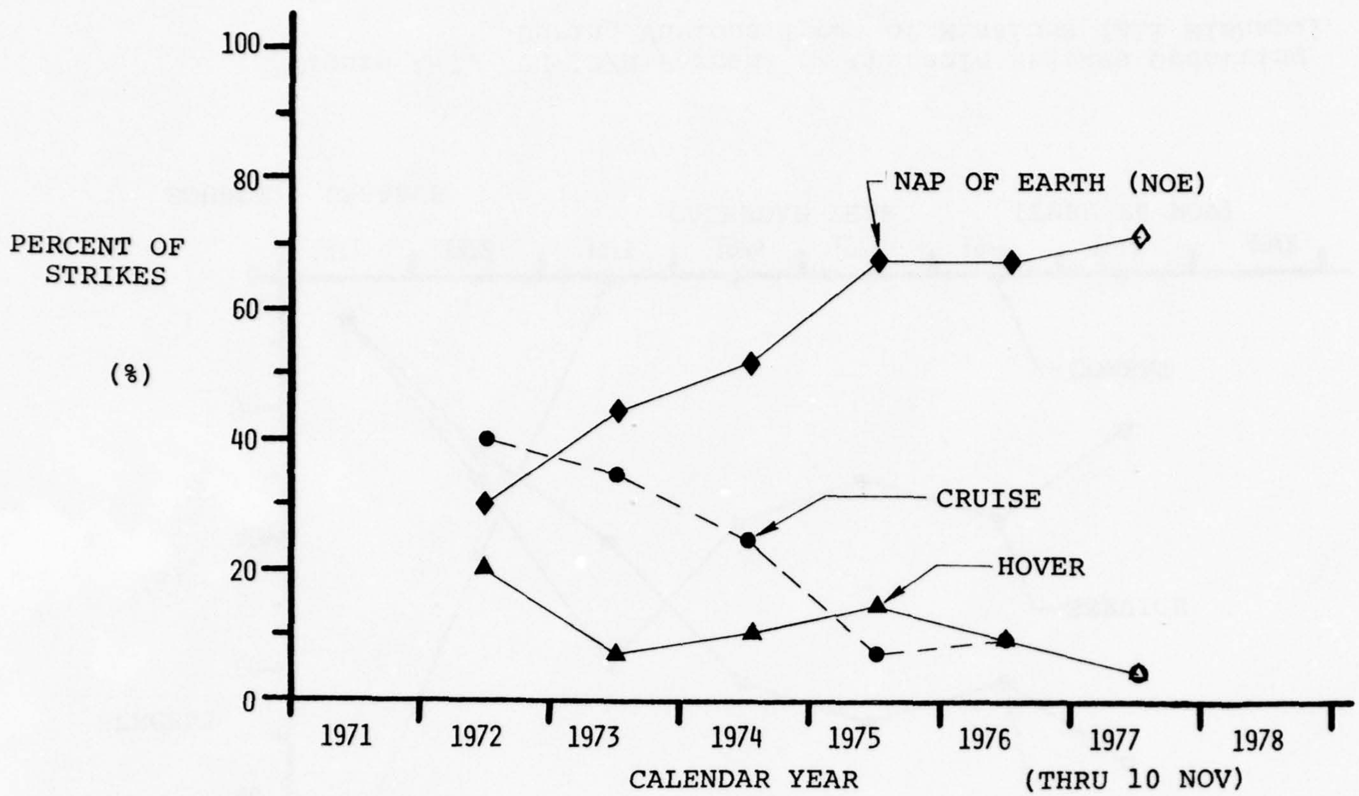
SOURCE: USAAAVS

Figure A-6. OH-58A Percent of Obstacle Strikes Occurring During Various Types of Missions (All Mishaps)



SOURCE: USAAAVS

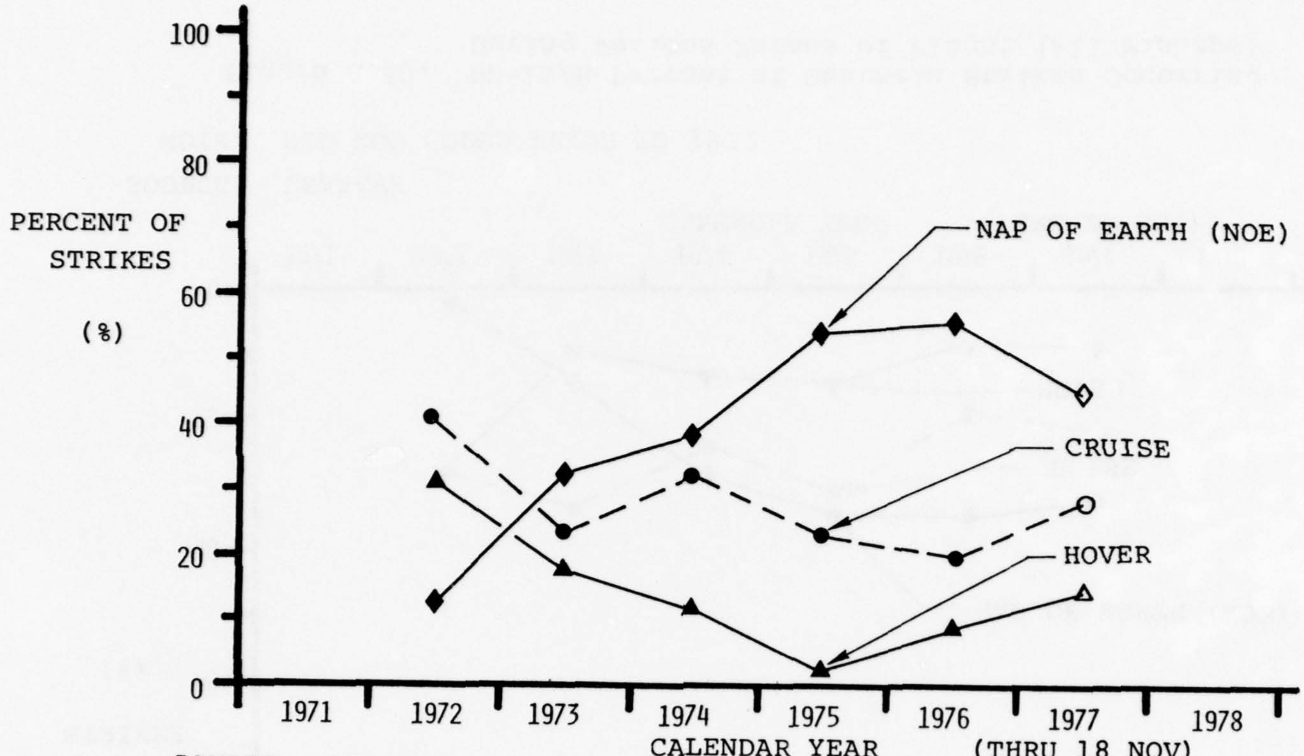
Figure A-7. UH-1D/H Percent of Obstacle Strikes Occurring During Various Types of Missions (All Mishaps)



SOURCE: USAAAVS

NOTE: NOE NOT CODED PRIOR TO 1972

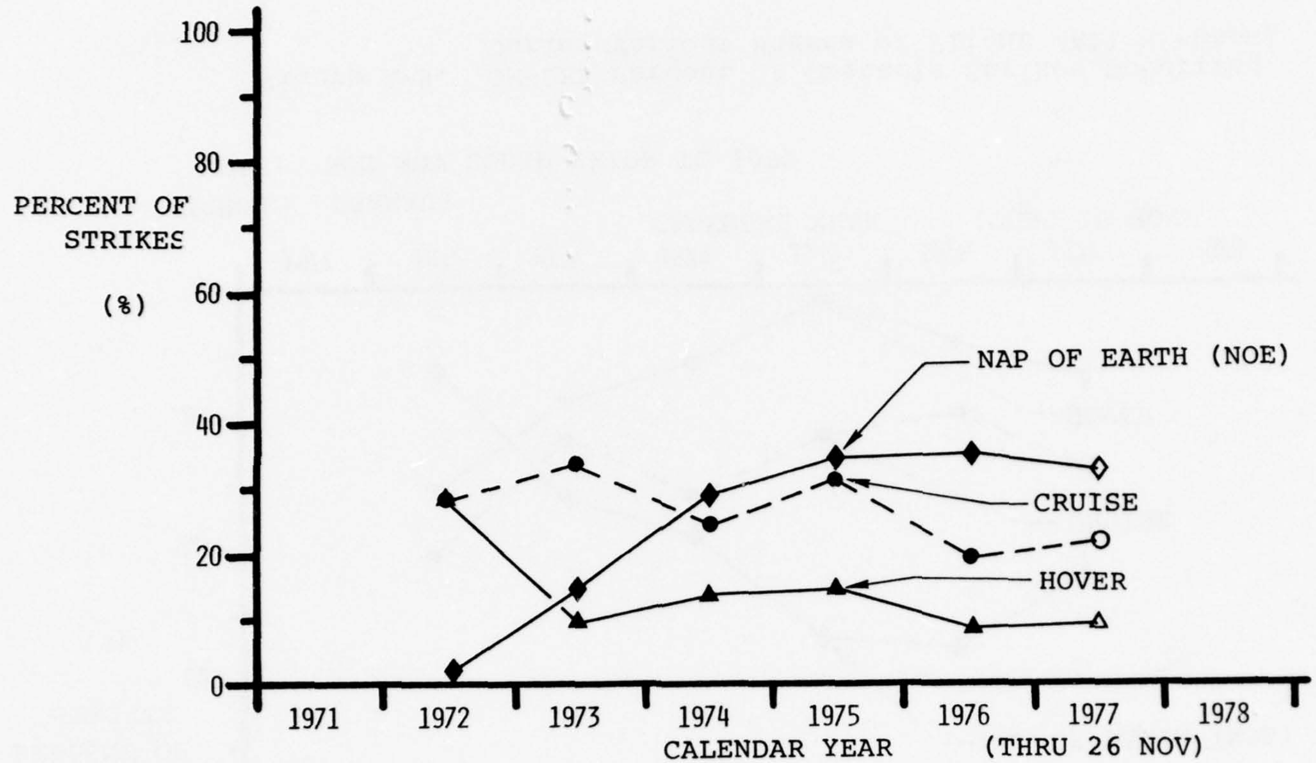
Figure A-8. AH-1/TH-1 Percent of Obstacle Strikes Occurring During Various Phases of Flight (All Mishaps)



SOURCE: USAAAVS

NOTE: NOE NOT CODED PRIOR TO 1972

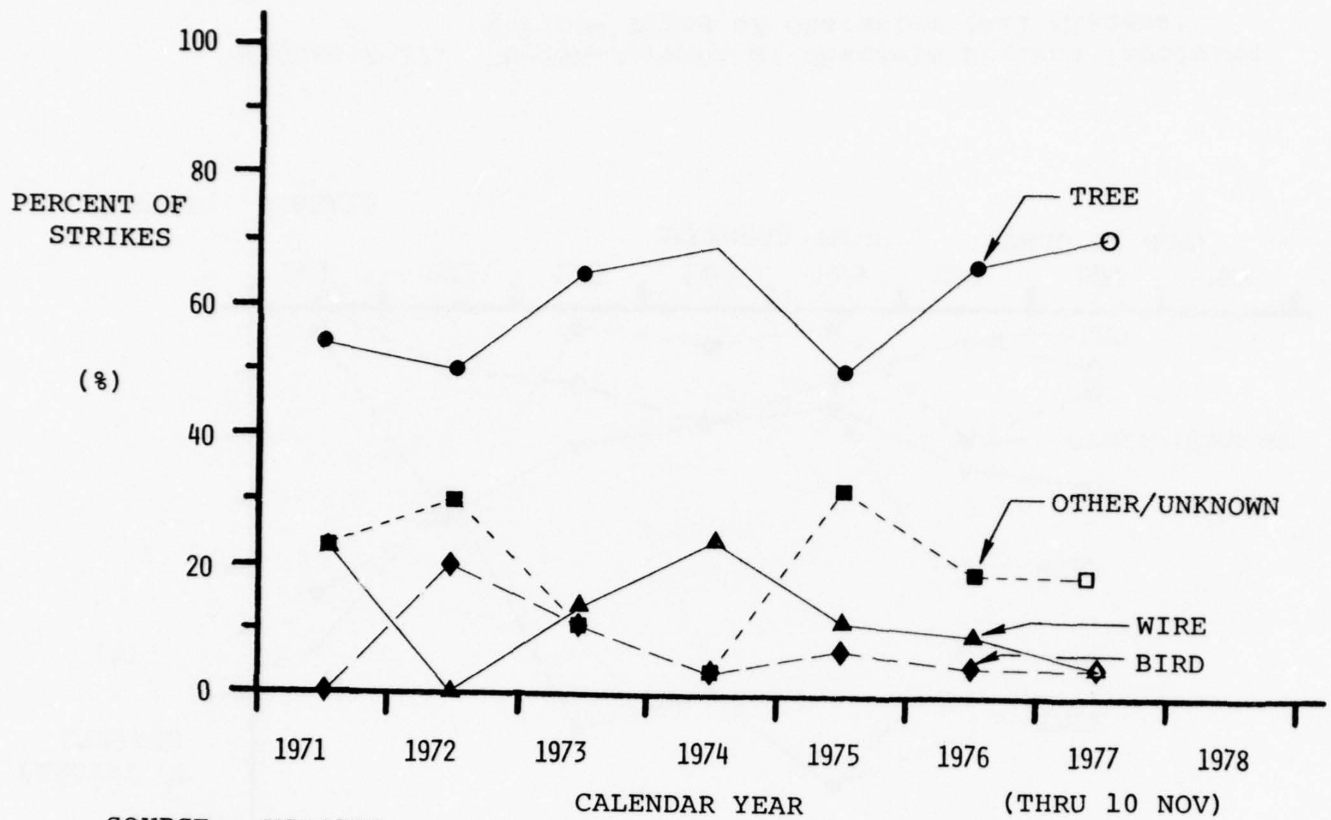
Figure A-9. OH-58A Percent of Obstacle Strikes Occurring During Various Phases of Flight (All Mishaps)



SOURCE: USAAAVS

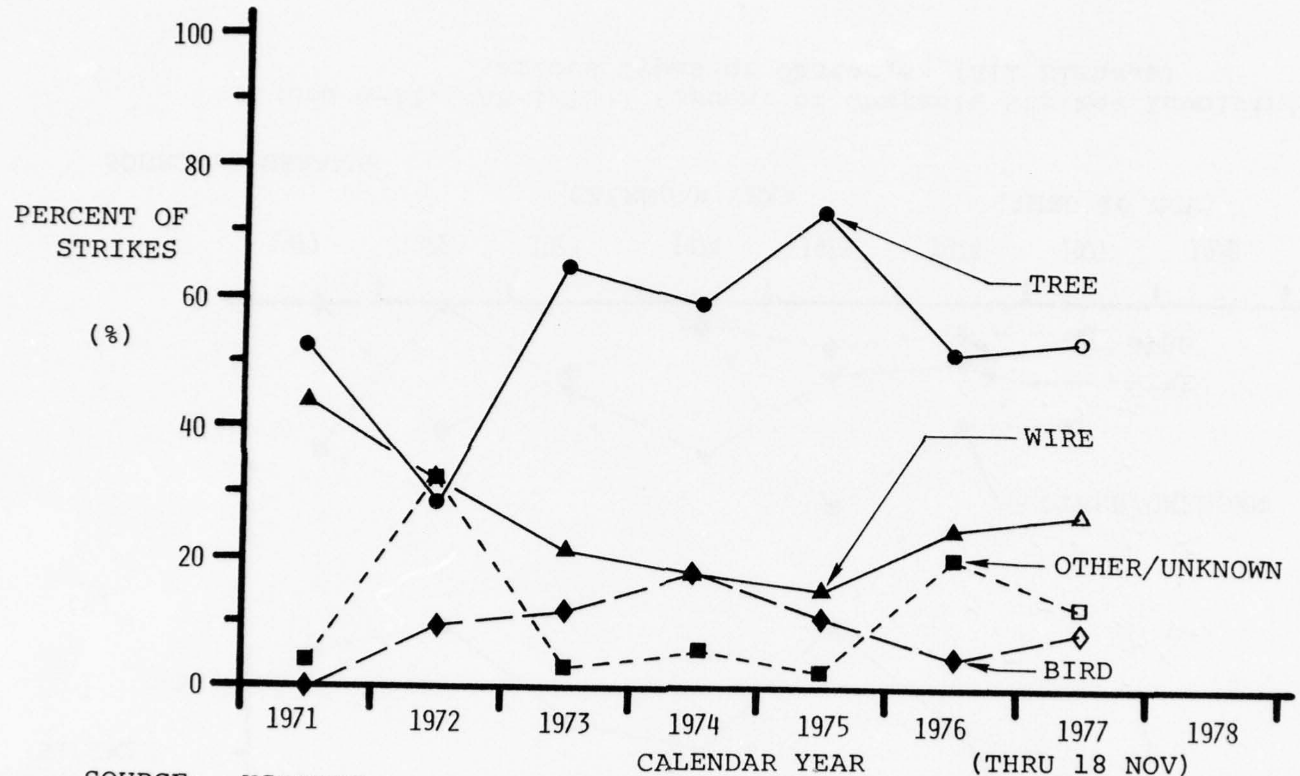
NOTE: NOE NOT CODED PRIOR TO 1972

Figure A-10. UH-1D/H Percent of Obstacle Strikes Occurring During Various Phases of Flight (All Mishaps)



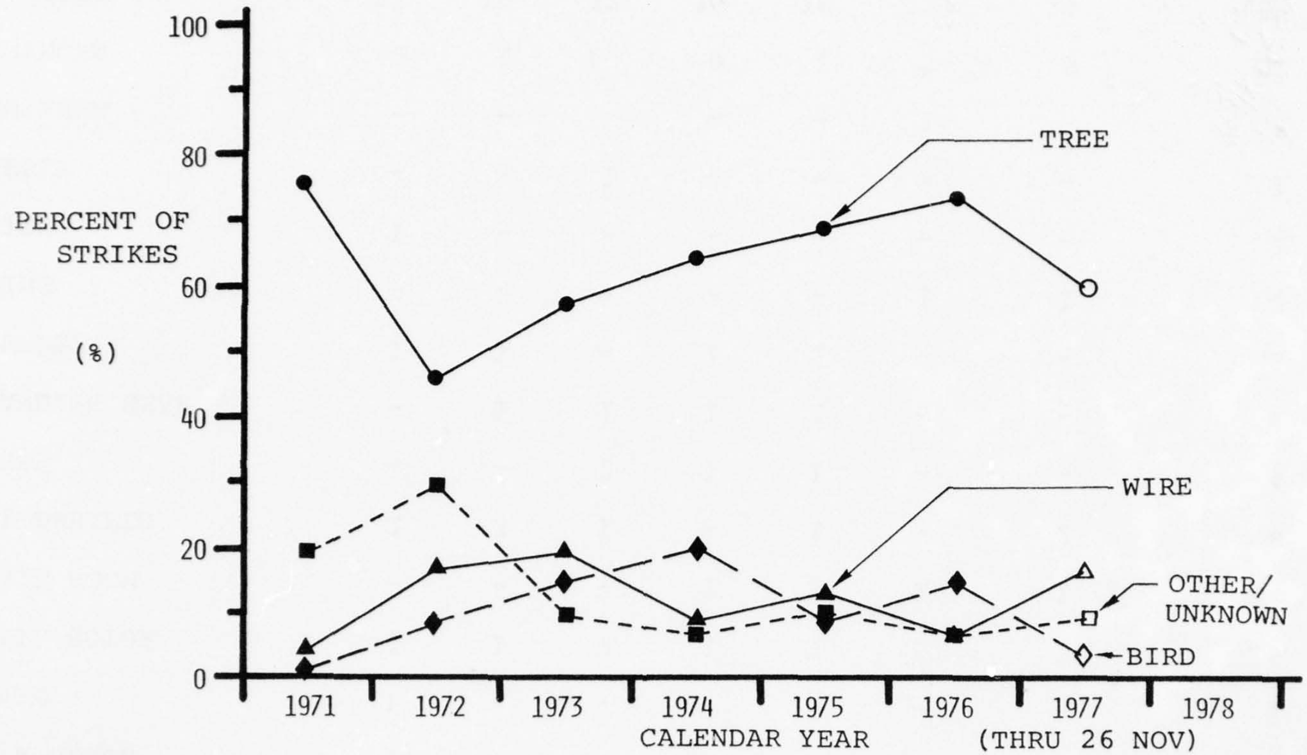
SOURCE: USAAAVS

Figure A-11. AH-1/TH-1 Percent of Obstacle Strikes Involving Various Types of Obstacles (All Mishaps)



SOURCE: USAAAVS

Figure A-12. OH-58A Percent of Obstacle Strikes Involving Various Types of Obstacles (All Mishaps)



SOURCE: USAAAVS

Figure A-13. UH-1D/H Percent of Obstacle Strikes Involving Various Types of Obstacles (All Mishaps)

TABLE A-13. AH-1/TH-1: WHERE OBSTACLE STRUCK AIRCRAFT
(NUMBER OF MISHAP OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(10 NOV) 1977	TOTALS 1971-1977	1972-1977
M/R BLADE	3	4	10	16	14	10	13	70	67
MAST	1	-	-	-	-	-	-	1	-
TAIL ROTOR	3	1	7	1	7	5	2	26	23
TAIL BOOM	-	-	-	1	1	1	1	4	4
WINDSHIELD	2	3	1	-	1	-	2	8	6
NOSE	-	-	2	1	1	-	-	4	4
LANDING GEAR	-	1	1	1	1	-	-	4	4
TURRET	1	1	-	1	2	-	-	5	4
WING	-	-	-	-	-	1	1	2	2
SIDE	1	-	-	-	-	-	-	1	-
BELLY	-	-	1	-	-	-	-	1	1
ANTENNA	-	-	-	-	-	1	-	1	1
UNKNOWN	3	1	10	9	1	3	5	32	29
TOTALS	14	10	32	30	28	21	24	159	145

SOURCE: USAAAVS

TABLE A-14. CH-47: WHERE OBSTACLE STRUCK AIRCRAFT
(NUMBER OF MISHAP OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(NOV) 1977	TOTALS 1971-1977	TOTALS 1972-1977
M/R BLADE	13	3	2	2	4	1	5	30	17
MAST	-	-	-	-	-	-	1	1	1
TAIL ROTOR	3	-	-	-	-	3	1	7	4
TAIL BOOM	-	-	-	-	-	-	-	-	-
WINDSHIELD	-	-	-	-	-	-	-	-	-
NOSE	-	-	1	-	-	-	-	1	1
LANDING GEAR	-	-	-	-	-	-	-	-	-
FUSELAGE	-	-	1	-	3	2	-	6	6
BELLY	-	-	-	-	-	-	2	2	2
UNKNOWN	2	-	-	-	2	3	1	8	6
TOTALS	18	3	4	2	9	9	10	55	37

SOURCE: USAAAVS

TABLE A-15. OH-6A: WHERE OBSTACLE STRUCK AIRCRAFT (NUMBER OF MISHAP OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(NOV) 1977	TOTALS 1971-1977	1972-1977
M/R BLADE	7	5	2	1	1	-	1	17	10
MAST	-	1	-	-	-	1	-	2	2
TAIL ROTOR	4	4	1	1	-	-	1	11	7
TAIL BOOM	-	-	-	-	-	-	1	1	1
WINDSHIELD	3	-	3	-	2	-	-	8	5
NOSE	1	2	-	-	-	-	-	3	2
LANDING GEAR	3	-	-	-	-	-	-	3	-
UNKNOWN	14	7	1	1	-	-	-	23	9
TOTALS	32	19	7	3	3	1	3	68	36

SOURCE: USAAAVS

TABLE A-16. OH-58A: WHERE OBSTACLE STRUCK AIRCRAFT (NUMBER OF MISHAP OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(18 NOV) 1977	TOTALS 1971-1977	TOTALS 1972-1977
M/R BLADE	8	14	23	19	31	26	29	150	142
MAST	2	2	1	-	1	3	1	10	8
TAIL ROTOR	3	4	5	1	3	8	5	29	26
TAIL BOOM	-	-	-	-	-	-	2	2	2
WINDSHIELD	1	2	1	3	2	2	5	16	15
NOSE	2	-	2	1	-	2	5	12	10
LANDING GEAR	2	-	-	1	2	-	1	6	4
WING	-	-	-	-	-	-	-	-	-
OTHER	-	3	1	-	-	-	4	8	8
UNKNOWN	7	7	1	10	10	9	4	48	41
TOTALS	25	32	34	35	49	50	56	281	256

SOURCE: USAAAVS

TABLE A-17. TH-55: WHERE OBSTACLE STRUCK AIRCRAFT
(NUMBER OF MISHAP OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(NOV) 1977	TOTALS 1971-1977	TOTALS 1972-1977
M/R BLADE	1	-	-	-	-	-	-	1	-
MAST	-	-	-	-	-	-	-	-	-
TAIL ROTOR	1	-	-	-	-	-	-	1	-
TAIL BOOM	-	-	-	-	-	-	-	-	-
WINDSHIELD	-	-	-	-	-	-	-	-	-
NOSE	-	-	-	-	1	-	-	1	1
LANDING GEAR	1	-	-	-	-	-	-	1	-
UNKNOWN	1	-	2	1	1	1	-	6	5
TOTALS	4	0	2	1	2	1	0	10	6

SOURCE: USAAAVS

TABLE A-18. UH-1D/H: WHERE OBSTACLE STRUCK AIRCRAFT (NUMBER OF MISHAP OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(26 NOV) 1977	TOTALS 1971-1977	1972-1977
M/R BLADE	133	33	27	30	33	52	32	340	207
MAST	-	-	-	-	1	-	-	1	1
TAIL ROTOR	31	8	-	2	6	6	4	58	27
TAIL BOOM	7	4	1	-	1	-	-	13	6
WINDSHIELD	1	-	1	2	3	6	2	14	13
NOSE	1	2	-	2	8	6	2	25	24
LANDING GEAR	5	2	4	-	-	1	3	11	6
WING	-	-	-	-	-	-	-	-	-
OTHERS:									
SWASHPLATE	-	-	-	-	-	-	2	2	2
XMSN. COWL	-	-	-	-	-	-	1	1	1
ELEVATOR	-	-	-	-	-	-	1	1	1
LANDING LIGHT	-	-	-	-	-	-	1	1	1
FM ANTENNA	-	-	-	-	-	-	1	1	1
UNKNOWN	35	12	9	9	18	12	12	107	72
TOTALS	213	61	42	45	70	83	61	575	362

SOURCE: USAAAVS

TABLE A-19. UH-1 (ALL): WHERE OBSTACLE STRUCK AIRCRAFT
(NUMBER OF OCCURRENCES)

AIRCRAFT AREA	CALENDAR YEAR 1971	1972	1973	1974	1975	1976	(NOV) 1977	TOTALS 1971-1977	1972-1977
M/R BLADE	136	33	27	30	35	57	33	351	215
MAST	-	-	-	-	1	-	-	1	1
TAIL ROTOR	32	8	1	2	6	6	4	59	27
TAIL BOOM	8	4	1	-	1	-	-	14	6
WINDSHIELD	1	-	-	3	3	6	2	15	14
NOSE	3	2	5	2	8	6	3	29	26
LANDING GEAR	7	3	-	-	-	-	3	14	7
WING	-	-	-	-	-	-	-	-	-
OTHERS	-	-	-	-	-	-	6	6	6
UNKNOWN	43	13	12	11	18	14	12	123	80
TOTALS	230	63	46	48	72	90	63	612	382

SOURCE: USAAAVS

APPENDIX B

OBSTACLE STRIKE SUMMARY SHEETS

TABLE B-1. SUMMARY C. ALL OBSTACLE STRIKES, AH-1

- CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	7	6	4	105	0	16	0	0	17	138
NO. MISHAPS W/INJURIES	5	3	0	0	0	0	0	0	8	8
TOTAL NO. INJURIES	8	4	0	0	0	0	0	0	12	12
NO. MISHAPS W/FATALITIES	4	0	0	0	0	0	0	0	4	4
TOTAL NO. FATALITIES	6	0	0	0	0	0	0	0	6	6
NO. NONSURVIVAL ACC.	2	0	0	0	0	0	0	0	2	2
NO. POST-CRASH FIRES	3	0	0	0	0	0	0	0	3	3
DAMAGE COST	3,568,831	837,214	294,866	618,802	0	0	0	0	4,700,911	5,319,713

- WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	7	128	3

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
4	-	-	1	1	1	-

VIS. OBSTRUCT ? YES	NO
4	-

YEAR: 1972-1977 (Jan. Thru 10 Nov. 77)

- FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	?
NO. MISHAPS	121	14	2	1

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
6	14	79	26	10	2	1

LOCATION CONUS	NONCONUS
101	37

TIME OF DAY	
DAWN	3
DAY	126
DUSK	2
NIGHT	7

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	8	95	9	13	11	8	5

ALT.AGL (EMERG.- TERMINATION) 0-50'	51'-100'	101'-500'	500'+
113	11	9	5

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	90	12	6	6	2	6	16

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
2	8	3	-

- OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	31	55	52

OBSCURED ? TOTAL	PARTIAL	NO
-	1	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	?
10	87	17	15	9

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	67	-	23	4	6	4	4	2
					LWR.FUSE.	TURRET	ANTENNA	?
					1	4	1	29

WIRE/CABLE PWR.	TELE.	GUY	?
5	5	-	7

TABLE B-2. SUMMARY D. OBSTACLE STRIKE ACCIDENTS ONLY, AH-1

- CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ 1-3	Σ 1-8
NO. MISHAPS	7	6	4						17	
NO. MISHAPS W/INJURIES	5	3	1						9	
TOTAL NO. INJURIES	8	4	1						13	
NO. MISHAPS W/FATALITIES	4	0	0						4	
TOTAL NO. FATALITIES	6	0	0						6	
NO. NONSURVIVAL ACC.	2	0	0						2	
NO. POST-CRASH FIRES	3	0	0						3	
DAMAGE COST	3,568,831	837,214	294,866						4,700,911	

- WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	-	13	4

VISABILITY AT OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ?	
YES	NO
-	-

YEAR: 1972-1977 (Jan. Thru 10 Nov. 77)

- FLIGHT

	MISSION			
	TRAIN.	SERV.	COMBAT	?
NO. MISHAPS	13	2	1	1

PHASE OF FLIGHT AT EMERGENCY						
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
1	1	6	6	2	1	

LOCATION	
CONUS	NONCONUS
11	6

	TIME OF DAY
DAWN	0
DAY	15
DUSK	1
NIGHT	1

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	2	11	3	2	1	1	

ALT. AGL (EMERG.- TERMINATION)			
0-50'	51'-100'	101'-500'	500'+
13	1	2	1

	AIRSPEED AT OBSTACLE IMPACT (KTS)						
	0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	6	1	1	1	2	3	3

ATTITUDE AT OBST. IMPACT			
HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

- OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	4	2	11

OBSCURED ?		
TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	?
-	7	4	3	3

	WHERE STRUCK AIRCRAFT							
	MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING
NO. MISHAPS	2	-	6	-	-	-	1	-
							Fuse.	?
							1	9

WIRE/CABLE			
PWR.	TELE.	GUY	?
2	1	-	1

TABLE B-3. SUMMARY E. WIRE STRIKE ACCIDENTS ONLY, AH-1

● CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	3	1	0						4	
NO. MISHAPS W/INJURIES	1	1	0						2	
TOTAL NO. INJURIES	1	1	0						2	
NO. MISHAPS W/FATALITIES	3	0	0						3	
TOTAL NO. FATALITIES	5	0	0						5	
NO. NONSURVIVAL ACC.	1	0	0						1	
NO. POST-CRASH FIRES	1	0	0						1	
DAMAGE COST	1,529,499	114,913	0						1,644,412	

● WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	-	3	1

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1972-1977

(Jan. Thru 10 Nov. 77)

● FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	3	1	0

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.
0	0	1	3	0	0

LOCATION CONUS	NONCONUS
4	0

	TIME OF DAY
DAWN	0
DAY	2
DUSK	1
NIGHT	1

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER
NO. MISHAPS	0	1	2	1	1	1

ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
3	0	1	0

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	0	1	0	0	1	0	2

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	2	-	1

● OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	4

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
		4	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING	?
NO. MISHAPS	1	-	1	-	-	-	-	-	3

WIRE/CABLE PWR.	TELE.	GUY	?
2	1	-	1

TABLE B-4. SUMMARY F. TREE STRIKE ACCIDENTS ONLY, AH-1

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	1*	4	2						7	
NO. MISHAPS W/INJURIES	1	1	0						2	
TOTAL NO. INJURIES	1	1	0						2	
NO. MISHAPS W/FATALITIES	1	0	0						1	
TOTAL NO. FATALITIES	1	0	0						1	
NO. NONSURVIVAL ACC.	0	0	0						0	
NO. POST-CRASH FIRES	1	0	0						1	
DAMAGE COST	509,833	454.435	77,987						1,042,255	

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	-	6	1

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1972-1977 (Jan. Thru 10 Nov. 77)

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	7	0	0	

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	
0	1	3	1	1	1	

LOCATION CONUS	NONCONUS
6	1

	TIME OF DAY
DAWN	0
DAY	7
DUSK	0
NIGHT	0

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	0	7	0	1	0	0	

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500+
6	0	1	0

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	5	0	0	0	0	2	0

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	2	1	4

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	
	7			

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING	?
NO. MISHAPS	1	-	4	-	-	-	-	-	2

WIRE/CABLE PWR.	TELE.	GUY

*STRIKE SECONDARY THIS CASE.

TABLE B-5. SUMMARY C. ALL OBSTACLE STRIKES, CH-34C

- CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	0	0	1	3	0	0	0	1	1	5
NO. MISHAPS W/INJURIES	0	0	0	0	0	0	0	0	0	0
TOTAL NO. INJURIES	0	0	0	0	0	0	0	0	0	0
NO. MISHAPS W/FATALITIES	0	0	0	0	0	0	0	0	0	0
TOTAL NO. FATALITIES	0	0	0	0	0	0	0	0	0	0
NO. NONSURVIVAL ACC.	0	0	0	0	0	0	0	0	0	0
NO. POST-CRASH FIRES	0	0	0	0	0	0	0	0	0	0
DAMAGE COST	0	0	87,570	2,047	0	0	0	2,409	87,570	92,026

- WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	1	4	-

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
1	-	-	-	-	-	-

VIS. OBSTRUCT.? YES	NO
-	-

YEAR: 1972-1977

- FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	3	1	-

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
2	1	-	-	1	-	1

LOCATION CONUS	NONCONUS
5	-

	TIME OF DAY
DAWN	0
DAY	4
DUSK	0
NIGHT	1

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER
NO. MISHAPS	4	3	-	-	1	-

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
4	-	-	1

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	4	-	-	-	1	-	-

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

- OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	?
1	1	2	-	1

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING	?
NO. MISHAPS	2	-	-	-	-	-	-	-	3

WIRE/CABLE PWR.	TELE.	GUY	?
-	-	-	2

TABLE B-6. SUMMARY C. ALL OBSTACLE STRIKES, CH-47

YEAR: 1972-1977

- CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	1	0	0	35	0	0	0	0	1	36
NO. MISHAPS W/INJURIES	0	0	0	0	0	0	0	0	0	0
TOTAL NO. INJURIES	0	0	0	0	0	0	0	0	0	0
NO. MISHAPS W/FATALITIES	1	0	0	0	0	0	0	0	1	1
TOTAL NO. FATALITIES	4	0	0	0	0	0	0	0	4	4
NO. NONSURVIVAL ACC.	1	0	0	0	0	0	0	0	1	1
NO. POST-CRASH FIRES	1	0	0	0	0	0	0	0	1	1
DAMAGE COST	3,024,417	0	0	1,012,192	0	0	0	0	3,024,417	4,036,609

- WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	5	31	-

	VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
NO. MISHAPS	2	1	-	-	-	-	1

	VIS. OBSTRUCT ? YES	NO
NO. MISHAPS	2	52

- FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	11	25	0	

	PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
NO. MISHAPS	3	9	3	8	7	-	1

	LOCATION CONUS	NONCONUS
NO. MISHAPS	26	10

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	14	12	2	4	2	5	1

	ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+	?
NO. MISHAPS	26	1	2	6	1

	TIME OF DAY
DAWN	1
DAY	26
DUSK	1
NIGHT	8

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	24	3	1	-	-	1	7

	ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
NO. MISHAPS	18			

- OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	-

	OBSCURED ? TOTAL	PARTIAL	NO
NO. MISHAPS	-	-	-

	TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	
NO. MISHAPS	8	11	1	16	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	17	1	4	-	-	1	-	-

	WIRE/CABLE PWR.	TELE.	GUY	
NO. MISHAPS	1	-	-	

TABLE B-7. SUMMARY C. ALL OBSTACLE STRIKES, OH-64

- CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ 1-3	Σ 1-8
NO. MISHAPS	3	5	0	21	0	4	0	0	8	33
NO. MISHAPS W/INJURIES	2	1	0	1	0	0	0	0	3	4
TOTAL NO. INJURIES	4	3	0	1	0	0	0	0	7	8
NO. MISHAPS W/FATALITIES	1	0	0	0	0	0	0	0	1	1
TOTAL NO. FATALITIES	3	0	0	0	0	0	0	0	3	3
NO. NONSURVIVAL ACC.	1	0	0	0	0	0	0	0	1	1
NO. POST-CRASH FIRES	0	0	0	0	0	0	0	0	0	0
DAMAGE COST	377,463	106,798	0	58,341	0	0	0	0	484,250	592,602

- WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	1	-	-

VISABILITY AT OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
1	-	-	-	-	-	-

VIS. OBSTRUCT ?	
YES	NO
1	-

YEAR: 1972-1977

- FLIGHT

	MISSION			
	TRAIN.	SERV.	COMBAT	
NO. MISHAPS	12	5	16	

PHASE OF FLIGHT AT EMERGENCY						
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
1	2	-	22	6	-	2

LOCATION	
CONUS	NONCONUS
15	17

	TIME OF DAY
DAWN	1
DAY	24
DUSK	1
NIGHT	7

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	3	12	4	6	6	1	3

ALT.AGL (EMERG.-TERMINATION)				
0-50'	51-100'	101-500'	500'+	?
21	3	5	5	5

	AIRSPEED AT OBSTACLE IMPACT (KTS)							
	0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	7	4	4	3	3	6	2	9

ATTITUDE AT OBST. IMPACT			
HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

- OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ?		
TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	?
10	11	6	4	

	WHERE STRUCK AIRCRAFT								
	MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING	?
NO. MISHAPS	10	2	7	1	5	2	-	-	9

WIRE/CABLE			
PWR.	TELE.	GUY	?
3	-	1	2

TABLE B-8. SUMMARY C. ALL OBSTACLE STRIKES, OH-13/TH-13

● CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ 1-3	Σ 1-8
NO. MISHAPS	2	0	0	1	0	0	0	0	2	3
NO. MISHAPS W/INJURIES	2	0	0	0	0	0	0	0	2	2
TOTAL NO. INJURIES	3	0	0	0	0	0	0	0	3	3
NO. MISHAPS W/FATALITIES	0	0	0	0	0	0	0	0	0	0
TOTAL NO. FATALITIES	0	0	0	0	0	0	0	0	0	0
NO. NONSURVIVAL ACC.	0	0	0	0	0	0	0	0	0	0
NO. POST-CRASH FIRES	0	0	0	0	0	0	0	0	0	0
DAMAGE COST	125,400	0	0	334	0	0	0	0	125,400	125,734

● WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	-	3	-

VISABILITY AT OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ?	
YES	NO
-	-

YEAR: 1972-1977

● FLIGHT

	MISSION		
	TRAIN.	SERV.	COMBAT
NO. MISHAPS	2	1	-

PHASE OF FLIGHT AT EMERGENCY					
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.
-	-	-	3	-	-

LOCATION	
CONUS	NONCONUS
3	-

	TIME OF DAY
DAWN	-
DAY	2
DUSK	-
NIGHT	1

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	-	1	-	1	-	-	1

ALT.AGL (EMERG.- TERMINATION)			
0-50'	51-100'	101-500'	500'+
-	-	-	3

	AIRSPEED AT OBSTACLE IMPACT (KTS)						
	0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	-	-	-	1	1	1	-

ATTITUDE AT OBST. IMPACT			
HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

● OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ?		
TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	?
1	-	-	1	1

	WHERE STRUCK AIRCRAFT								
	MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING	?
NO. MISHAPS	-	-	1	-	-	1	-	-	1

WIRE/CABLE		
PWR.	TELE.	GUY
-	-	-

TABLE B-9. SUMMARY C. ALL OBSTACLE STRIKES, OH-23

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	4	3	0	6	0	0	0	0	7	13
NO. MISHAPS W/INJURIES	3	0	0	0	0	0	0	0	3	3
TOTAL NO. INJURIES	4	0	0	0	0	0	0	0	4	4
NO. MISHAPS W/FATALITIES	1	0	0	0	0	0	0	0	1	1
TOTAL NO. FATALITIES	1	0	0	0	0	0	0	0	1	1
NO. NONSURVIVAL ACC.	1	0	0	0	0	0	0	0	1	1
NO. POST-CRASH FIRES	1	0	0	0	0	0	0	0	1	1
DAMAGE COST	110,633	49,645	0	8,628	0	0	0	0	240,278	248,906

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	-	13	-

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1971-1972

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	10	3	-

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
1	1	-	2	3	2	2

LOCATION CONUS	NONCONUS
13	0

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER
NO. MISHAPS	1	3	6	5	2	1

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+	?
11	-	1	-	1

TIME OF DAY	
DAWN	0
DAY	11
DUSK	1
NIGHT	1

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	7	-	2	1	1	-	-	2

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ? TOTAL	PARTIAL	NO
-	2	11

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
-	4	7	2

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING
NO. MISHAPS	5	1	4	-	1	2	-	-

WIRE/CABLE PWR.	TELE.	GUY
5	-	-

TABLE B-10. SUMMARY C. ALL OBSTACLE STRIKES, OH-58A

• CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ 1-3	Σ 1-8
NO. MISHAPS	26	10	6	170	0	28	0	1	42	242
NO. MISHAPS W/INJURIES	14	1	1	1	0	0	0	0	1	17
TOTAL NO. INJURIES	30	1	1	1	0	0	0	0	33	33
NO. MISHAPS W/FATALITIES	9	0	0	0	0	0	0	0	9	9
TOTAL NO. FATALITIES	13	0	0	0	0	0	0	0	13	13
NO. NONSURVIVAL ACC.	7	0	0	0	0	0	0	0	7	7
NO. POST-CRASH FIRES	0	0	0	0	0	0	0	0	0	0
DAMAGE COST	3,426,780	266,277	48,328	525,118	0	0	0	2,314	3,737,385	4,262,407

• WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	18	222	2

VISABILITY AT OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
11	-	1	-	-	2	6

VIS. OBSTRUCT ?	
YES	NO
12	230

YEAR: 1972-1977

• FLIGHT

	MISSION			
	TRAIN.	SERV.	COMBAT	
NO. MISHAPS	168	69	5	

PHASE OF FLIGHT AT EMERGENCY						
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
17	21	109	37	25	4	29

LOCATION	
CONUS	NONCONUS
182	60

TIME OF DAY	
DAWN	3
DAY	207
DUSK	11
NIGHT	21

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	20	151	30	24	10	28	4

ALT. AGL (EMERG.- TERMINATION)				
0-50'	51-100'	101-500'	500'+	?
199	7	4	18	14

	AIRSPEED AT OBSTACLE IMPACT (KTS)							
	0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	124	25	10	16	4	29	8	26

ATTITUDE AT OBST. IMPACT			
HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ?		
TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	?
24	138	52	24	4

	WHERE STRUCK AIRCRAFT							
	MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	142	8	26	2	15	10	4	-

WIRE/CABLE			
PWR.	TELE.	GUY	?
15	16	-	20

OTHER = 1

TABLE B-11. SUMMARY E. WIRE STRIKE ACCIDENTS ONLY, OH-58A

YEAR: 1972-1977 (Jan. Thru 18 Nov. 77)

- **CASUALTY DATA**

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	17	6	2						25	
NO. MISHAPS W/INJURIES	11	1	1						13	
TOTAL NO. INJURIES	24	1	1						26	
NO. MISHAPS W/FATALITIES	4	0	0						4	
TOTAL NO. FATALITIES	4	0	0						4	
NO. NONSURVIVAL ACC.	2	0	0						2	
NO. POST-CRASH FIRES	0	0	0						0	
DAMAGE COST	2,217,017	160,883	11,622						2,389,522	

- **WEATHER**

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	3	4	18

	VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
NO. MISHAPS	-	-	1	-	-	-	-

	VIS. OBSTRUCT ? YES	NO
NO. MISHAPS	1	-

- **FLIGHT**

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	12	12	1

	PHASE OF FLIGHT AT EMERGENCY ~~TAKE-OFF~~	HOVER	NOE	CRUISE	LAND.	AUTO.
NO. MISHAPS	3	3	2	-	2	1

	LOCATION CONUS	NONCONUS
NO. MISHAPS	15	10

TIME OF DAY	
DAWN	0
DAY	22
DUSK	2
NIGHT	1

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER
NO. MISHAPS	3	5	10	4	-	7

	ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
NO. MISHAPS	19	2	3	1

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	9	2	2	3	1	7	1

	ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
NO. MISHAPS	-	-	-	-

- **OBSTACLE**

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	25

	OBSCURED ? TOTAL	PARTIAL	NO
NO. MISHAPS	-	-	-

	TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
NO. MISHAPS			25	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING
NO. MISHAPS	4	5	-	1	3	-	1	-
		M/R CONT.		STRG	COWL			?
		2		1	1			10

	WIRE/CABLE PWR.	TELE.	GUY	*	?
NO. MISHAPS	8	6	-	2	9

*CONCERTINA

TABLE B-12. SUMMARY G. ALL WIRE STRIKES, OH-58A

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	17	6	2	24	0	5	0	0	25	54
NO. MISHAPS W/INJURIES	11	1	1	0	0	0	0	0	13	13
TOTAL NO. INJURIES	24	1	1	0	0	0	0	0	26	26
NO. MISHAPS W/FATALITIES	4	0	0	0	0	0	0	0	4	4
TOTAL NO. FATALITIES	4	0	0	0	0	0	0	0	4	4
NO. NONSURVIVAL ACC.	2	0	0	0	0	0	0	0	2	2
NO. POST-CRASH FIRES	0	0	0	0	0	0	0	0	0	0
DAMAGE COST	2,217,017	160,883	11,622	43,934	0	0	0	0	2,383,522	2,433,456

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	7	7	40

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
1	-	1	-	1	1	-

VIS. OBSTRUCT ? YES	NO
3	-

YEAR: 1972-1977 (Jan. Thru 18 Nov. 77)

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	27	25	2

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.
7	5	14	18	9	1

LOCATION CONUS	NONCONUS
34	20

	TIME OF DAY
DAWN	2
DAY	44
DUSK	5
NIGHT	3

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	9	15	16	11	-	11	2

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
43	4	5	2

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	23	7	5	5	2	10	2

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	2	3	49

OBSCURED ? TOTAL	PARTIAL	NO
2	1	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
		54	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	7	6	5	2	13	4	3	-

M/R CONTR	SERVO MTS	STRG	FM ANT.	COWL	SIDE	?
1	1	1	6	1	1	11

WIRE/CABLE PWR.	TELE.	GUY	TOW	*	?
17	13	1	1	2	21

*CONCERTINA

TABLE B-13. SUMMARY C. ALL OBSTACLE STRIKES, TH-55A

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	TOTALS Σ 1-8
NO. MISHAPS	4	0	0	2	0	0	0	0	4	6
NO. MISHAPS W/INJURIES	2	0	0	0	0	0	0	0	2	2
TOTAL NO. INJURIES	3	0	0	0	0	0	0	0	3	3
NO. MISHAPS W/FATALITIES	1	0	0	0	0	0	0	0	1	1
TOTAL NO. FATALITIES	1	0	0	0	0	0	0	0	1	1
NO. NONSURVIVAL ACC.	1	0	0	0	0	0	0	0	1	1
NO. POST-CRASH FIRES	0	0	0	0	0	0	0	0	0	0
DAMAGE COST	142,501	0	0	393	0	0	0	0	142,501	142,894

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS		3	3

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1972-1977

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	6	-	-	

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	
-	-	-	3	-	3	

LOCATION CONUS	NONCONUS
6	-

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	-	4	2	1	-	-	

ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+	?
3	1	-	-	2

TIME OF DAY	
DAWN	-
DAY	6
DUSK	-
NIGHT	-

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	-	-	1	4	-	-	-	1

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	6

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	?
1	2	1		2

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING	?
NO. MISHAPS	-	-	-	-	-	1	-	-	5

WIRE/CABLE PWR.	TELE.	GUY	?
-	-	-	1

TABLE B-14. SUMMARY C. ALL OBSTACLE STRIKES, UH-1B/C/M

- CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	1	2	1	12	0	4	0	0	4	20
NO. MISHAPS W/INJURIES	0	1	0	0	0	0	0	0	1	1
TOTAL NO. INJURIES	0	4	0	0	0	0	0	0	4	4
NO. MISHAPS W/FATALITIES	1	0	0	0	0	0	0	0	1	1
TOTAL NO. FATALITIES	2	0	0	0	0	0	.0	0	2	2
NO. NONSURVIVAL ACC.	1	0	0	0	0	0	0	0	1	1
NO. POST-CRASH FIRES	1	0	0	0	0	0	0	0	1	1
DAMAGE COST	244,760	119,344	87,955	82,162	0	72	0	0	452,059	435,293

- WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	3	5	12

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
1	-	-	-	1	-	1

VIS. OBSTRUCT ? YES	NO
2	-

YEAR: 1972-1977

- FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	19	1	-	

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	
1	-	6	10	1	2	

LOCATION CONUS	NONCONUS
16	4

	TIME OF DAY
DAWN	1
DAY	12
DUSK	1
NIGHT	5

? = 1

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	2	12	3	1	1	1	3

ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
13	2	2	3

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	3	3	1	1	2	6	-	3

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

- OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	3	-	17

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	
3	10	6	1	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	8	-	-	-	1	2	1	-

WIRE/CABLE PWR.	TELE.	GUY	?
-	-	-	6

TABLE B-15. SUMMARY C. ALL OBSTACLE STRIKES, UH-1D/H

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	21	15	1	248	0	71	0	0	37	356
NO. MISHAPS W/INJURIES	16	7	1	3	0	0	0	0	24	27
TOTAL NO. INJURIES	54	16	1	4	0	0	0	0	71	75
NO. MISHAPS W/FATALITIES	11	0	0	0	0	0	0	0	11	11
TOTAL NO. FATALITIES	43	0	0	0	0	0	0	0	43	43
NO. NONSURVIVAL ACC.	4	0	0	0	0	0	0	0	4	4
NO. POST-CRASH FIRES	5	0	0	0	0	0	0	0	5	5
DAMAGE COST	8,603,084	1,096,372	47,867	1,035,905	0	0	0	0	9,747,323	10,783,228

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	24	322	10

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
15	1	2	-	-	1	4

VIS. OBSTRUCT ? YES	NO
10	

YEAR: 1972-1977

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	ST
NO. MISHAPS	202	127	26	1

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
45	49	90	93	53	-	20

LOCATION CONUS	NONCONUS
262	94

	TIME OF DAY
DAWN	4
DAY	295
DUSK	16
NIGHT	41

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	131	218	12	50	38	12	4

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+	?
215	28	14	32	67

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	131	23	15	12	10	44	11	109

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	326

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	?
40	223	4	-	9

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	-	1	27	6	13	24	6	-

OTHER	?
6	72

WIRE/CABLE PWR.	TELE.	GUY	?
16	7	1	18

TABLE B-16. SUMMARY D. OBSTACLE STRIKE ACCIDENTS ONLY, UH-1H

YEAR: 1975-1977 (Jan 26 Thru Nov. 77)

- **CASUALTY DATA**

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	14	6	0						20	
NO. MISHAPS W/INJURIES	9	4	0						13	
TOTAL NO. INJURIES	45	9	0						54	
NO. MISHAPS W/FATALITIES	6	0	0						6	
TOTAL NO. FATALITIES	23	0	0						23	
NO. NONSURVIVAL ACC.	3	0	0						3	
NO. POST-CRASH FIRES	5	0	0						5	
DAMAGE COST	6,377,875	405,379	0						6,783,254	

- **WEATHER**

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	3	13	4

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	1	-	-	-	1

VIS. OBSTRUCT ? YES	NO
-	-

- **FLIGHT**

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	11	9	0	

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	
1	1	2	9	3	4	

LOCATION CONUS	NONCONUS
15	5

	TIME OF DAY
DAWN	0
DAY	15
DUSK	0
NIGHT	5

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	0	12	3	4	4	0	

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
14	5	1	0

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	9	1	1	2	3	4	0

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

- **OBSTACLE**

	SEEN ? YES	NO	UNK.
NO. MISHAPS	1	-	19

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	
0	12	7	1	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING	?
NO. MISHAPS	3	-	3	-	1	-	-	-	14

WIRE/CABLE PWR.	TELE.	GUY	?
2	-	-	5

TABLE B-17. SUMMARY E. WIRE STRIKE ACCIDENTS ONLY, UH-1H

YEAR: 1975-1977 (Jan. 26 Thru Nov. 1977)

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	4	3	0						7	
NO. MISHAPS W/INJURIES	2	2	0						4	
TOTAL NO. INJURIES	3	6	0						9	
NO. MISHAPS W/FATALITIES	3	0	0						3	
TOTAL NO. FATALITIES	10	0	0						10	
NO. NONSURVIVAL ACC.	1	0	0						1	
NO. POST-CRASH FIRES	2	0	0						2	
DAMAGE COST	1,204,195	231,055	0						1,435,250	

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	-	7	-

	VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
NO. MISHAPS	-	-	-	-	-	-	-

	VIS. OBSTRUCT ? YES	NO
NO. MISHAPS	-	-

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	5	2	0	

	PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	
NO. MISHAPS	0	0	1	4	1	1	

	LOCATION CONUS	NONCONUS
NO. MISHAPS	3	4

TIME OF DAY	
DAWN	0
DAY	5
DUSK	0
NIGHT	2

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	0	2	2	2	1	0	

	ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
NO. MISHAPS	5	1	1	0

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	3	0	0	0	1	3	0

	ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
NO. MISHAPS	-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	1	-	6

	OBSCURED ? TOTAL	PARTIAL	NO
NO. MISHAPS	-	-	-

	TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	
NO. MISHAPS			7		

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING	?
NO. MISHAPS	-	-	3	-	1	-	-	-	4

	WIRE/CABLE PWR.	TELE.	GUY	?
NO. MISHAPS	2	-	-	5

TABLE B-18. SUMMARY F. TREE STRIKE ACCIDENTS ONLY, UH-1H

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	9	3	0						12	
NO. MISHAPS W/INJURIES	6	1	0						7	
TOTAL NO. INJURIES	40	3	0						43	
NO. MISHAPS W/FATALITIES	3	0	0						3	
TOTAL NO. FATALITIES	13	0	0						13	
NO. NONSURVIVAL ACC.	2	0	0						2	
NO. POST-CRASH FIRES	2	0	0						2	
DAMAGE COST	3,937,570	174,324	0						4,111,894	

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	4	7	1

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	1	-	-	-	1

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1975-1977

(Jan. 26 Thru Nov. 1977)

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	6	6	0

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.
1	1	0	5	2	3

LOCATION CONUS	NONCONUS

	TIME OF DAY
DAWN	0
DAY	9
DUSK	0
NIGHT	3

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER
NO. MISHAPS	0	10	0	2	2	0

ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
8	3	1	0

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	6	0	1	2	2	1	0

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	12

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
	12		

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING	?
NO. MISHAPS	2	-	-	-	-	-	-	-	10

WIRE/CABLE PWR.	TELE.	GUY

TABLE B-19. SUMMARY G. ALL WIRE STRIKES, UH-1H

● CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	4	3	0	9	0	8	0	0	7	24
NO. MISHAPS W/INJURIES	2	2	0	1	0	0	0	0	4	5
TOTAL NO. INJURIES	2	6	0	1	0	0	0	0	8	9
NO. MISHAPS W/FATALITIES	3	0	0	0	0	0	0	0	3	3
TOTAL NO. FATALITIES	10	0	0	0	0	0	0	0	10	10
NO. NONSURVIVAL ACC.	1	0	0	0	0	0	0	0	1	1
NO. POST-CRASH FIRES	2	0	0	0	0	0	0	0	2	2
DAMAGE COST	1,812,250	231,055	0	49,254	0	0	0	0	2,053,305	2,102,559

● WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	1	21	2

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR:
1975-1977
(Jan. 26 Thru Nov. 1977)

● FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	14	10	0

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.
2	0	7	10	4	1

LOCATION CONUS	NONCONUS
8	16

TIME OF DAY	
DAWN	1
DAY	20
DUSK	0
NIGHT	3

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	2	9	3	4	4	1	5

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
16	5	3	0

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	11	2	2	3	1	5	0

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

● OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	7	3	14

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
		24	

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING
NO. MISHAPS	2	-	3	-	3	2	4	-

SUPL	?
1	13

WIRE/CABLE PWR.	TELE.	GUY	KITE	?
6	4	-	1	13

TABLE B-20. SUMMARY C. ALL OBSTACLE STRIKES, ALL R/W

YEAR: 1972-1977

• CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ 1-3	Σ 1-8
NO. MISHAPS	67	39	13	600	0	124	0	2	119	845
NO. MISHAPS W/INJURIES	42	16	2	5	0	0	0	0	60	65
TOTAL NO. INJURIES	104	31	2	6	0	0	0	0	137	143
NO. MISHAPS W/FATALITIES	30	0	0	0	0	0	0	0	30	30
TOTAL NO. FATALITIES	75	0	0	0	0	0	0	0	75	75
NO. NONSURVIVAL ACC.	19	0	0	0	0	0	0	0	19	19
NO. POST-CRASH FIRES	11	0	0	0	0	0	0	0	11	11
DAMAGE COST	22,586,862	2,434,570	562,486	3,339,990	0	72	0	4,732	25,583,918	28928,703

• WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	58	752	35

VISABILITY AT OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
25	2	3	1	2	4	12

VIS. OBSTRUCT ?	
YES	NO
31	43

• FLIGHT

	MISSION			
	TRAIN.	SERV.	COMBAT	?
NO. MISHAPS	548	245	49	3

PHASE OF FLIGHT AT EMERGENCY							
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	GND	?
75	107	276	236	102	10	11	28

LOCATION	
CONUS	NONCONUS
621	224

	TIME OF DAY
DAWN	13
DAY	705
DUSK	32
NIGHT	94
?	1

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	?
NO. MISHAPS	181	509	63	102	68	56	46

ALT. AGL (EMERG.- TERMINATION)				
0-50'	51-100'	101-500'	500'+	?
597	54	35	72	87

	AIRSPEED AT OBSTACLE IMPACT (KTS)							
	0-15	16-30	31-45	46-60	61-75	76-90	90+	?
NO. MISHAPS	387	70	38	45	24	92	44	145

ATTITUDE AT OBST. IMPACT			
HORIZ.	ROLL	PITCH UP	PITCH DN
22	8	4	-

• OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	57	82	706

OBSCURED ?		
TOTAL	PARTIAL	NO
12	16	4

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	?
99	482	134	99	31

	WHERE STRUCK AIRCRAFT							
	M/R	MAST	T/R	TB	W/SHIELD	NOSE	LND. GEAR	WING
NO. MISHAPS	445	12	99	13	40	46	16	?

OTHER	?
13	154

WIRE/CABLE				
PWR.	TELE.	GUY	OTH.	?
40	28	2	4	60

TABLE B-21. SUMMARY E. WIRE STRIKE ACCIDENTS ONLY, ALL ROTARY WING

• CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	30	16	2						48	
NO. MISHAPS W/INJURIES	18	5	1						24	
TOTAL NO. INJURIES	40	9	1						50	
NO. MISHAPS W/FATALITIES	12	0	0						12	
TOTAL NO. FATALITIES	31	0	0						31	
NO. NONSURVIVAL ACC.	2	0	0						2	
NO. POST-CRASH FIRES	2	0	0						2	
DAMAGE COST	6,221,664	711,484	11,622						6,944,770	

• WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	3	9	36

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1972-1977 (Jan. Thru Nov. 77)

• FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	27	20	1	

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
4	6	8	3	3	7	17

LOCATION CONUS	NONCONUS
32	16

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	3	13	19	12	4	21	

ALT. AGL (EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
35	4	5	4

TIME OF DAY	
DAWN	0
DAY	36
DUSK	4
NIGHT	8

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	18	6	2	5	4	9	4

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

• OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	?
		48		

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	6	5	6	3	4	0	1	0

COWL - 1 TAIL STINGER - 1
M/R CONTROL - 2 UNKNOWN - 24

WIRE/CABLE PWR.	TELE.	GUY	?
18	7	2	

BARB WIRE - 1
CONCERTINA - 3
UNKNOWN - 17

TABLE B-22. SUMMARY F. TREE STRIKE ACCIDENTS ONLY, ALL R/W

- CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	24	16	7						47	
NO. MISHAPS W/INJURIES	13	5	0						18	
TOTAL NO. INJURIES	44	12	0						56	
NO. MISHAPS W/FATALITIES	11	0	0						11	
TOTAL NO. FATALITIES	26	0	0						26	
NO. NONSURVIVAL ACC.	7	0	0						7	
NO. POST-CRASH FIRES	6	0	0						6	
DAMAGE COST	9,497,491	942,524	222,295						10,662,310	

- WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	12	35	0

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
5	0	1	0	1	0	6

VIS. OBSTRUCT ? YES	NO
13	1

YEAR: 1972-1977

- FLIGHT

	MISSION TRAIN.	SERV.	COMBAT
NO. MISHAPS	26	17	4

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.
2	4	15	5	8	13

LOCATION CONUS	NONCONUS
37	10

	TIME OF DAY
DAWN	0
DAY	36
DUSK	2
NIGHT	9

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER
NO. MISHAPS	0	47	0	7	4	47

ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
27	6	10	4

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	34	1	2	2	2	3	3

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
0	23	16	11

- OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	13	6	14

OBSCURED ? TOTAL	PARTIAL	NO
4	7	6

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER
	47		

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	8	0	10	0	0	0	0	0

WIRE/CABLE PWR.	TELE.	GUY

UNKNOWN PART OF A/C = 29

TABLE B-23. SUMMARY G. ALL WIRE STRIKES, ALL R/W

● CASUALTY DATA

	MISHAP CLASS 1	2	3	4	5	6	7	8	TOTALS Σ 1-3	Σ 1-8
NO. MISHAPS	30	16	2	64	0	22	0	0	48	134
NO. MISHAPS W/INJURIES	18	5	1	1	0	0	0	0	24	25
TOTAL NO. INJURIES	40	9	1	1	0	0	0	0	50	51
NO. MISHAPS W/FATALITIES	12	0	0	0	0	0	0	0	12	12
TOTAL NO. FATALITIES	31	0	0	0	0	0	0	0	31	31
NO. NONSURVIVAL ACC.	2	0	0	0	0	0	0	0	2	2
NO. POST-CRASH FIRES	2	0	0	0	0	0	0	0	2	2
DAMAGE COST	6,221,664	711,484	11,622	193,889	0	0	0	0	6,944,770	7,138,659

● WEATHER

	FACTOR ? YES	NO	UNK.
NO. MISHAPS	11	9	36

VISABILITY AT OBSTACLE IMPACT (NM) 0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
-	-	-	-	-	-	-

VIS. OBSTRUCT ? YES	NO
-	-

YEAR: 1972-1977

● FLIGHT

	MISSION TRAIN.	SERV.	COMBAT	
NO. MISHAPS	70	61	3	

PHASE OF FLIGHT AT EMERGENCY TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
17	11	55	10	17	7	17

LOCATION CONUS	NONCONUS
85	49

	TERRAIN OF CRASH SITE PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	21	38	36	30	14	21	

ALT.AGL(EMERG.- TERMINATION) 0-50'	51-100'	101-500'	500'+
108	10	12	4

	TIME OF DAY
DAWN	4
DAY	106
DUSK	11
NIGHT	13

	AIRSPEED AT OBSTACLE IMPACT (KTS) 0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	77	12	10	7	7	14	6

ATTITUDE AT OBST. IMPACT HORIZ.	ROLL	PITCH UP	PITCH DN
-	-	-	-

● OBSTACLE

	SEEN ? YES	NO	UNK.
NO. MISHAPS	-	-	-

OBSCURED ? TOTAL	PARTIAL	NO
-	-	-

TYPE OBSTACLE BIRD	TREE	WIRE	OTHER	
		134		

	WHERE STRUCK AIRCRAFT MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	20	8	10	4	15	6	11	0

WIRE/CABLE PWR.	TELE.	GUY	
50	20	2	

OTHER = 11
UNKNOWN = 51

OTHER PARTS OF A/C = 69

TABLE B-24. SUMMARY H. ALL TREE STRIKES, ALL R/W

• CASUALTY DATA

	MISHAP CLASS								TOTALS	
	1	2	3	4	5	6	7	8	Σ 1-3	Σ 1-8
NO. MISHAPS	24	16	7	358	0	54			47	459
NO. MISHAPS W/INJURIES	13	5	0	2	0	0			18	20
TOTAL NO. INJURIES	44	12	0	2	0	0			56	58
NO. MISHAPS W/FATALITIES	11	0	0	0	0	0			11	11
TOTAL NO. FATALITIES	26	0	0	0	0	0			26	26
NO. NONSURVIVAL ACC.	7	0	0	0	0	0			7	7
NO. POST-CRASH FIRES	6	0	0	0	0	0			6	6
DAMAGE COST	9,497,491	942,524	222,295	1,558,884		0			10,662,310	12,221,194

• WEATHER

	FACTOR ?		
	YES	NO	UNK.
NO. MISHAPS	37	422	0

VISABILITY AT OBSTACLE IMPACT (NM)						
0-1/8	1/8-1/4	1/4-1/2	1/2-1	1-2	2-3	3+
5	0	1	0	1	0	6

VIS. OBSTRUCT ?	
YES	NO
13	1

YEAR: 1972-1977

• FLIGHT

	MISSION			
	TRAIN.	SERV.	COMBAT	
NO. MISHAPS	330	105	24	

PHASE OF FLIGHT AT EMERGENCY						
TAKE-OFF	HOVER	NOE	CRUISE	LAND.	AUTO.	?
48	71	245	15	58	15	7

LOCATION	
CONUS	NONCONUS
355	104

TIME OF DAY	
DAWN	7
DAY	402
DUSK	16
NIGHT	34

	TERRAIN OF CRASH SITE						
	PREP.	TREES	OPEN	LEVEL	MTS.	OTHER	
NO. MISHAPS	9	459	32	97	38	50	

ALT. AGL (EMERG.- TERMINATION)			
0-50'	51-100'	101-500'	500'+
416	19	17	7

	AIRSPEED AT OBSTACLE IMPACT (KTS)						
	0-15	16-30	31-45	46-60	61-75	76-90	90+
NO. MISHAPS	405	14	7	12	5	8	8

ATTITUDE AT OBST. IMPACT			
HORIZ.	ROLL	PITCH UP	PITCH DN
0	23	16	11

• OBSTACLE

	SEEN ?		
	YES	NO	UNK.
NO. MISHAPS	13	6	14

OBSCURED ?		
TOTAL	PARTIAL	NO
4	7	6

TYPE OBSTACLE				
BIRD	TREE	WIRE	OTHER	
	459			

	WHERE STRUCK AIRCRAFT							
	MRB	MAST	T/R	TB	W/SHIELD	NOSE	LND.GEAR	WING
NO. MISHAPS	321	0	52	4	0	15	2	0

WIRE/CABLE			
PWR.	TELE.	GUY	

UNKNOWN PART OF A/C = 77

APPENDIX C

ANALYSIS OF BLADE STRIKE

The typical tip speeds associated with helicopter main or tail rotors are in the neighborhood of 750 feet/sec which should impose very high loading rates in a strike. The strike situation is somewhat analogous to breaking a wooden or concrete block using a karate chop. In a karate chop, one attains a high speed at impact and keeps the wrist very rigid. This procedure minimizes the deceleration of the hand during the strike and, consequently, the high-speed impact initiates a stress wave of sufficient amplitude (amplitude being proportional to the velocity of strike) to cause fracture. It might be possible that the "built up" structure of a hand, i.e., skin, muscle, bone, etc., damps the shock of deceleration rapidly to minimize damage to the hand. Another frequently observed phenomenon occurring in nature is the penetration of straws into telephone poles during hurricanes. Again, the mechanism could possibly be explained in terms of a stress wave.

The present blade strike analysis is based on a local rupture energy consideration where, in a strike, the energy transfer takes place through stress wave initiation. A succession of such "microimpacts" are used to calculate the blade loading during a strike.

Let the blade be moving at a velocity V_o at the instant of a strike. The equation for dynamics of stress wave is given by

$$\frac{m\partial^2 y}{\partial t^2} = -\rho c \delta_2 \left(V_0 + \frac{\partial y}{\partial t}\right) \qquad \text{(C-1)}$$

where

m = mass distribution per unit length of the blade at the point of contact, lb-sec^2/in.^{2}

c = velocity of longitudinal elastic stress wave in the impacted object = $E_{/\rho}$; if the local level is such that proportionately, the limit is exceeded, it is equal to $(d\sigma/d\varepsilon)/\rho$ at the load level, in./sec.

δ_2 = area of contact in the impact, in.^{2}

y = particle displacement at axial location, x in.

The solution for particle displacement is given by

$$y = -V_o x \exp\left(\frac{x-ct}{c\tau}\right) \qquad \text{(C-2)}$$

where

τ = time constant for energy transfer = $\frac{m}{\rho c \delta_2}$ sec

The energy balance in a microimpact can be described as follows:

The blade penetrates from x by a distance dx to x+dx. The energy dissipated is

$= E_\gamma[A\ (x + dx) - A\ (x)]$

$d_{d\chi} = V_{dt}$, V = instantaneous velocity, and

E_r = rupture energy required to create unit area of ruptured surface in a charpy type of impact test.

Using the kinetic energy calculation, the force level can be calculated as

$$F(t) = \frac{1}{2}\ \frac{mhV^2(t)\ \{1 - e^{-2dt/\tau}\}}{Vdt} \qquad \text{(C-3)}$$

The impact integral which is proportional to impact damage is defined as

$$z = \int_{o}^{\Delta t} F(t)dt \qquad \text{(C-4)}$$

Δt = duration of strike